

# **A NON-POINT SOURCE OF CONTAMINANTS TO THE ESTUARINE FOOD WEB:**

submitted to Science Program 2006

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lead investigators:

Torres, Raymond

Goni, Miguel

Bergamaschi, Brian

Fleck, Jacob

# Project Information And Executive Summary

## A NON-POINT SOURCE OF CONTAMINANTS TO THE ESTUARINE FOOD WEB:

This is proposal #0070 for the Science Program 2006 solicitation.

Frequently asked questions and answers for this PSP are now available.

The submission deadline for this proposal has passed. Proposals may not be changed.

### Instructions

Please complete the Project Information and Executive Summary Form prior to proceeding to the other forms contained on this website and required to be completed as part of your PSP application submittal. Information provided on this form will automatically support subsequent forms to be completed as part of the Science PSP submission process. Information provided on this form will appear in the Contacts and Project Staff, Task and Budget Summary, and Conflict of Interest forms.

*Proposal Title: A NON-POINT SOURCE OF CONTAMINANTS TO THE ESTUARINE FOOD WEB:*

*This field is limited to 255 characters. All proposal titles must be entered in title case. No abbreviations or acronyms will be accepted.*

### Applicant Information

*Applicant Organization Name: University of South Carolina*

*Please provide the name of the organization submitting the application as follows: Davis, California University of; Fish and Game, California Department of; California Waterfowl Association, etc.*

*Applicant Organization Type:*

**public institution of higher education**  
eligibility

Below, please provide contact information for the representative of the applicant organization who is authorized to enter into a contractual agreement with the State of California and who has overall responsibility for the operation, management, and reporting requirements of the applicant organization. (This should be the same individual who signs the signature page.)

Salutation: **Professor**

First Name: **Raymond**

Last Name: **Torres**

Street Address: **701 Sumter Street**

City: **Co,umbia**

State or Province: **SC**

Zip Code or Mailing Code: **29208**

Telephone: **803 777-4506**

E-mail Address: **torres@geol.sc.edu**

Below, please provide contact information for the primary point of contact for the implementation of the proposal. This person should be the same individual who is serving as the project Lead Investigator/Project Director.

Salutation: **Professor**

First Name: **Raymond**

Last Name: **Torres**

Telephone: **803 777-4506**

E-mail Address: **torres@geol.sc.edu**

### Proposal Information

Total Amount Requested: \$877,982

The figure represented above is provided by the total amount requested on your completed Task and Budget Summary Form. The applicant must ensure the amount indicated above is correct and equal to the total amount requested in the budget document uploaded via the Budget and Justification Form for this project.

Select one primary and up to three secondary topic areas that best apply to this proposal:

**Environmental Water** (Primary)

**Habitat Availability and Response to Change**

**Trends and Patterns of Populations and System Response to a Changing Environment**

Select up to five keywords to describe this project.

- *agriculture*
- *agricultural economics*
- *agricultural engineering*
- *agronomy*
- *agro-ecology*
- *benthic invertebrates*
- *benthos*
- *biochemistry*
- *biological indicators*
- *birds*
- *channels and sloughs*
- *climate change*
- *conservation or agricultural easements*
- *conservation program management*
- *database management*
- X *ecotoxicology*
- *economics*
- *engineering*
- *erosion control*
- *environmental education*
- *evapotranspiration*
- *fish biology*
- *delta smelt*
- *salmon and steelhead*
- *other species*
- *otoliths*
- *tagging*
- *fish management and facilities*
- *flooded islands*
- *floodplains and bypasses*
- *forestry*
- *genetics*
- *geochemistry*
- *geographic information systems (GIS)*
- *geology*
- X *geomorphology*
- *groundwater*
- *human health*
- *hydrodynamics*
- *hydrology*
- *insects*
- *integrated pest management*
- *integrated resource planning*
- *invasive species / non-native species / exotic species*
- *irrigation systems*
- *land use laws and regulations*
- *land use management*
- *land use planning and policy*
- *levees*
- *mammals*
- *microbiology / bacteriology*
- *conceptual*
- *quantitative*
- *oceanography*
- *performance measures*
- *phytoplankton*

- *plants*
- *terrestrial*
- *aquatic*
- *wetland*
- *remote sensing / imaging*
- *reptiles*
- *reservoirs and lakes*
- *restoration*
- *riparian zone*
- *rivers and streams*
- X *sediment*
- *soil science*
- *statistics*
- *subsidence*
- *sustainable agriculture*
- *trophic dynamics and food webs*
- *water operations (diversions, pumps, intakes, exports, barriers, gates, etc.)*
- X *water quality*
- *other*
- *temperature*
- X *contaminants*
- *nutrients, organic carbon, and oxygen depleting substances*
- *salinity*
- *sediment and turbidity*
- *water supply*
- *watershed assessment*
- *watershed management*
- *wetlands*
- *zooplankton*

Provide the geographic coordinates that best describe the center point of your project. (Note: If your project has more than one site, provide a center point that best captures the central location.)

Example:      Latitude:        38.575; must be between 30 and 45  
                          Longitude:    -121.488; must be between -120 and  
                                                 -130

#### Help for finding a geographic location.

Latitude: **38.02**  
 Longitude: **-122.04**

Provide the number miles radius from the center point provided above, to demonstrate the radius of the entire project.

**30**

Provide a description of the physical location of your project. Describe the area using information such as water bodies, river miles and road intersections.

#### **Intertidal landscapes of the Bay-Delta areas.**

Successful applicants are responsible for complying with all applicable laws and regulations for their projects, including the National Environmental Policy Act (NEPA) and the California Environmental Quality Act (CEQA). Projects funded through this PSP that tier off the CALFED Programmatic EIS/EIR must incorporate applicable mitigation strategies described in the CALFED Programmatic Record of Decision to avoid or minimize the project's adverse environmental impacts. Applicants are encouraged to review the Programmatic EIS/EIR and incorporate the applicable mitigation strategies from Appendix A of these documents for their projects.

If you anticipate your project will require compliance of this nature (ie applications for permits, other environmental documentation), provide below a list of these items, as well as the status of those applications or processes, if applicable. If you believe your project will not require these regulatory actions, please provide one or two lines of text outlining why your proposed project will not be subject to these processes. Further guidance is available in The Guide to Regulatory Compliance for Implementing CALFED Activities.

**not applicable**

Is this proposal an application for next phase funding of an ongoing project funded by CALFED Science Program?

☒ No. – Yes.

If yes, identify the ongoing project:

Project Title:

CALFED Contract Management Organization:

Amount Funded:

Date Awarded:

Lead Organization:

Project Number:

Have primary staff and/or subcontractors of the project team (those persons listed on the Contacts and Project Staff form) received funding from CALFED for a project not listed above?

☒ No. – Yes.

If yes, list the projects below: (only list up to the five most recent projects)

Project Title:

CALFED Contract Management Organization:

Amount Funded:

Date Awarded:

Lead Organization:

Project Number:

Project Title:

CALFED Contract Management Organization:

Amount Funded:

Date Awarded:

Lead Organization:

Project Number:

Project Title:

CALFED Contract Management Organization:

Amount Funded:

Date Awarded:

Lead Organization:

Project Number:

Project Title:

CALFED Contract Management Organization:

Amount Funded:

Date Awarded:

Lead Organization:

Project Number:

Project Title:

CALFED Contract Management Organization:

Amount Funded:

Date Awarded:

Lead Organization:

Project Number:

Has the Lead Investigator, the applicant organization, or other primary staff or subcontractors of your project team ever submitted a proposal for this effort or a similar effort to any CALFED PSP?

☒ No. – Yes.

If yes, list the submission below: (only list up to the five most recent projects)

Project Title:

CALFED Program:

Date of PSP:

Project Title:

CALFED Program:

Date of PSP:

Project Title:

CALFED Program:

Date of PSP:

Project Title:

CALFED Program:

Date of PSP:

Project Title:

CALFED Program:

Date of PSP:

*Note: Additional information on this or prior applications submitted -- or proposals funded -- may be required of applicants.*

List people you feel are qualified to serve as scientific and/or technical reviewers for this proposal and are not associated with your organization or CALFED.

Full Name	Organization	Telephone	E-Mail	Expertise
John Callaway	USF	510 684-0559	callaway@usfca.edu	
Joy Zedler	U Wisconsin	608-262-8629	jbzedler@wisc.edu	
Ray Pestrong	SF State University	415 338-2080	rayp@sfsu.edu	

Provide additional comments, information, etc. here:

## Executive Summary

Provide a brief but complete summary description of the proposed project; its geographic location; project objective; project type, approach to implement the proposal; expected outcomes; and adaptive management approach and relationship to the Science Program goals. The Executive Summary should be a concise, informative, stand-alone description of the proposed project and be no longer than one page in length. Please note, this information will be made public on our website shortly after the closing date of this PSP.

Many fish and birds in the San Francisco Delta and Estuary exhibit high levels of contaminants (metals and organic pollutants), which have been shown to affect their behavior and reproductive success, yet routes of exposure and assimilation pathways remain unclear. Understanding the pathways by which contaminants are assimilated is essential to appropriately manage habitat areas.

The interplay of physical, chemical and biological processes in shallow and intertidal habitats provides a significant unquantified pathway of exposure. It remains unquantified because it is difficult to measure. The shallow and intertidal areas are trophically important because algae and microorganisms that live there excrete polymers that increase the food value of the sediment. But the polymers also preferentially concentrate mercury, metals and other contaminants. And they increase the effective sediment grain size after resuspension, causing them to be grazed at higher trophic levels than the fine-grained sediments themselves.

The goals of this research are to quantify the process of contaminant concentration and resuspension of shallow and intertidal cohesive sediments at sites along the salinity gradient from Prospect Island to San Pablo Bay. There are three components to the study: 1) a geochemical investigation of the contaminant concentration, nutritive quality, and carbon source in resuspended sediments; 2) a field investigation that quantifies the physical, environmental, and chemical properties that control contaminant concentration and resuspension; and 3) a synthesis of the study results in a regional model that identifies the areas where biota would be most susceptible to this route of exposure, and that could be used to forecast the effects of land-use and climate change.

# Contacts And Project Staff

This is proposal #0070 for the Science Program 2006 solicitation.

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## INSTRUCTIONS

Use this form to provide titles, affiliations, qualifications, and descriptions of roles of the primary and secondary project staff. Include any consultants, subcontractors and/or vendors. The Lead Investigator or Project Director, as identified in the Project Information and Executive Summary Form, is required to upload a PDF version of their resume. To complete the qualification field of this form, please provide a bulleted list of relevant project/field experience and any publications/reports that support your participation in the proposed project.

Information provided on this form will automatically support subsequent forms to be completed as part of the Science Program PSP submission process. Please note that information you enter in this form will appear in the Task and Budget Summary and Conflict of Interest forms.

Information on subcontractor services must be provided even if the specific service provider has not yet been selected. If the specific subcontractor has not been identified or selected, please list TBD (to be determined) in the last name field and the anticipated service type in the title field (example: Fish Biologist).

Please provide this information before continuing to the Tasks and Deliverables Form.

## Applicant

University of South Carolina  
Professor Raymond Torres  
701 Sumter Street  
Columbia SC 29208  
803 777-4506  
torres@geol.sc.edu

## Lead Investigator/Project Director

Salutation: **Professor**  
Last Name: **Torres**  
First Name: **Raymond**  
Title: **Professor**  
Organization: **University of South Carolina**  
Responsibilities: **Project Director**  
Resume:

*You have already uploaded a PDF file for this question. Review the file to verify that appears correctly.*

Mailing Address: **701 Sumter Street, EWS 617**  
City: **Columbia**  
State: **SC**  
Zip: **29208**  
Telephone: **803 777-4506**  
E-Mail: **torres@geol.sc.edu**

## All Other Personnel

Salutation: **Professor**  
Last Name: **Goni**  
First Name: **Miguel**  
Title: **Professor**  
Organization: **University of Oregon**  
Position:

**Co-PI**

Responsibilities: **Geochemical Analyses**

Qualifications:

**Organic Geochemical Analyses of Particulate Organic Carbon**

*List relevant project/field experience and publications/reports.*

Salutation: **Dr.**

Last Name: **Bergamaschi**

First Name: **Brian**

Title: **Research Chemist**

Organization: **USGS Water Science Center**

Position:

**Co-PI**

Responsibilities: **Geochemical-Physical Analyses**

Qualifications:

**Organic Geochemical Analyses of Dissolved Organic Carbon**

*List relevant project/field experience and publications/reports.*

Salutation: **Mr.**

Last Name: **Fleck**

First Name: **Jacob**

Title: **Hydrologist/Soil Scientist**

Organization: **USGS Water Science Center**

Position:

**Co-PI**

Responsibilities: **Physical Properties of Sediment**

Qualifications:

**Optical Properties of Particulates, Geochemical Analyses**

*List relevant project/field experience and publications/reports.*



# Conflict Of Interest

This is proposal #0070 for the Science Program 2006 solicitation.

[Frequently asked questions and answers for this PSP are now available.](#)

The submission deadline for this proposal has passed. Proposals may not be changed.

## Instructions

To assist Science Program staff in managing potential conflicts of interest as part of the review and selection process, we are requesting applicants to provide information on who will directly benefit if your proposal is funded. Please provide the names of individuals who fall in the following categories and are not listed in the Personnel Form:

- Persons listed in the proposal, who wrote the proposal, will be performing the tasks listed in the proposal, or who will benefit financially if the proposal is funded; and/or
- Subcontractors listed in the proposal, who will perform tasks listed in the proposal, or will benefit financially if the proposal is funded.

Applicant  
Submittor  
Lead Investigator/Project Director  
Primary Staff  
Secondary Staff  
Subcontractor

Provide the list of names and organizations of all individuals not listed in the proposal who helped with proposal development along with any comments.

Last Name	First Name	Organization	Role
Downing	Bryan	USGS Water Science Center	Collaborator

# Task And Budget Summary

This is proposal #0070 for the Science Program 2006 solicitation.

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## Instructions

Use the table below to delineate the tasks needed to carry out your proposal. Tasks in this form should support the narrative description of your project in your proposal document and the information provided in your detailed budget spreadsheet. Each task and subtask must have a number, title, timeline, list of personnel or subcontractors providing services, and associated budget figure.

When creating subtasks, ensure that each activity is counted only once. Please note, the initial task of your table (Task 1) must present all project management/administrative activities supporting your overall proposal.

For proposals involving multiple agencies or organizations (including subcontractors), the table must clearly state the tasks and subtasks performed by each entity.

Task #	Task Title	Start Month	End Month	Personnel Involved	Description	Task Budget
1	Project administration	1	30	Torres, Raymond	See proposal text	12,290
2	Physical, hydrodynamic and meteorological field measurements	1	30	Torres, Raymond Bergamaschi, Brian Fleck, Jacob	See proposal text	261,880
3	Laboratory physical and chemical characterization of sediments	4	18	Torres, Raymond Goni, Miguel	See proposal text	203,470
4	Laboratory physical and chemical characterization of mobilized particles and dissolved constituents	4	18	Torres, Raymond Goni, Miguel	See proposal text	191,661
5	Physical, chemical and optical characterization of mobilized particles and dissolved constituents in the field	1	30	Torres, Raymond Bergamaschi, Brian Fleck, Jacob	See proposal text	83,382
6	Partitioning and redox effects on metals cycling	4	18	Bergamaschi, Brian Fleck, Jacob	See proposal text	80,150
7	Modeling intertidal contributions to system turbidity and biotic contamination	18	24	Fleck, Jacob	See proposal text	45,149

total budget=\$877,982

# Detailed Budget Upload And Justification

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Using the budget provided via this link as a guide, please complete a budget for your proposal in the software of your choice (e.g. Excel). This document must be in a format and software that can be converted to PDF prior to uploading on the web system.

It is incumbent upon the applicant to fully explain/justify the significant costs represented in the attached budget. This information can be provided either in a text document and uploaded below, or included in your proposal text in a clearly defined budget justification section. If it is not abundantly clear to reviewers what project costs are commensurate with which efforts and benefits, the proposal may receive a poor review and denied funding.

Costs for each task described in the Task and Budget Summary Form and each staff or subcontractor described on the Contacts and Project Staff Form, must be included in your budget. The budget for Task One should represent project management activities, including but not limited to cost verification, environmental compliance, data handling, report preparation, project oversight, and public outreach. The total amount of your budget must equal the total amount represented on your Task and Budget Summary Form and the total budget amount represented on your Project Information and Executive Summary Form.

In a separate text document to be uploaded below, identify any cost share and other matching funds available to support your proposed project. If you identify cost share or matching funds, you must also describe them in the text of your proposal (see explanation of "cost share and other matching funds" in Section Two of the solicitation document).

CBDA may request additional information pertaining to the items, rates and justification of the information presented in your budget. Applications without completed budgets will not be considered for funding.

## Uploading The Completed Budget Template

First, convert your completed Budget to a PDF file. Then, use the browse function to locate the PDF version of your document, select the document and click on the upload prompt below.

*You have already uploaded this document. [View it](#) to verify that it appears as you expect. You may replace it by uploading another document*

## Uploading The Completed Budget Justification

First, convert your completed Justification text to a PDF file. Then, use the browse function to locate the PDF version of your document, select the document and click on the upload prompt below.

*You have already uploaded this document. [View it](#) to verify that it appears as you expect. You may replace it by uploading another document*

## Uploading The Description Of Cost Share/Matching Funds

First, convert your completed Description of Cost Share/Matching Funds text file to a PDF file. Then, use the browse function to locate the PDF version of your document, select the document and click on the upload prompt below.

*You have already uploaded this document. [View it](#) to verify that it appears as you expect. You may replace it by uploading another document*

# Schedule Of Deliverables

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Use the table below to delineate the key deliverables and the time necessary to complete them (in months from the date the project's grant agreement is executed). Each Science Program 2006 PSP grant recipient must provide the required minimum deliverables for each project. The required minimum deliverables for each funded proposal are as follows:

- Semi-annual report(s)
- Final Report
- One page project summary for public audience at beginning of project
- One page project summary for public audience upon project completion
- Project closure summary report or copy of draft manuscript
- Presentation at CALFED Science Conference
- Presentations at other events at request of CALFED Science Program staff
- Copy of all published material resulting from the grant

Deliverable	Description	Delivered By: # (In Months From Project Start Date)
Final report	Final summary report for project	30
Final report	Task 2 Journal Article	30
Final report	Task 3 Data report	30
Final report	Task 4 Data report	30
Final report	Task 5 Journal Article	30
Final report	Task 6 Journal Article	30
Final report	Task 7 Report with model	30
Semiannual reports	all tasks	6

If you are unable to provide a Schedule of Deliverables as outlined above, please provide your justification of non-compliance in the text box provided below. The Science Program reserves the right to determine a proposal non-eligible based on an applicants inability to provide the materials requested above.

All task and final reports will be delivered at end of project

# **AN NON-POINT SOURCE OF CONTAMINANTS TO THE ESTUARINE FOOD WEB: MOBILIZED PARTICLES FROM THE INTERTIDAL ZONE**

## **Research Purpose**

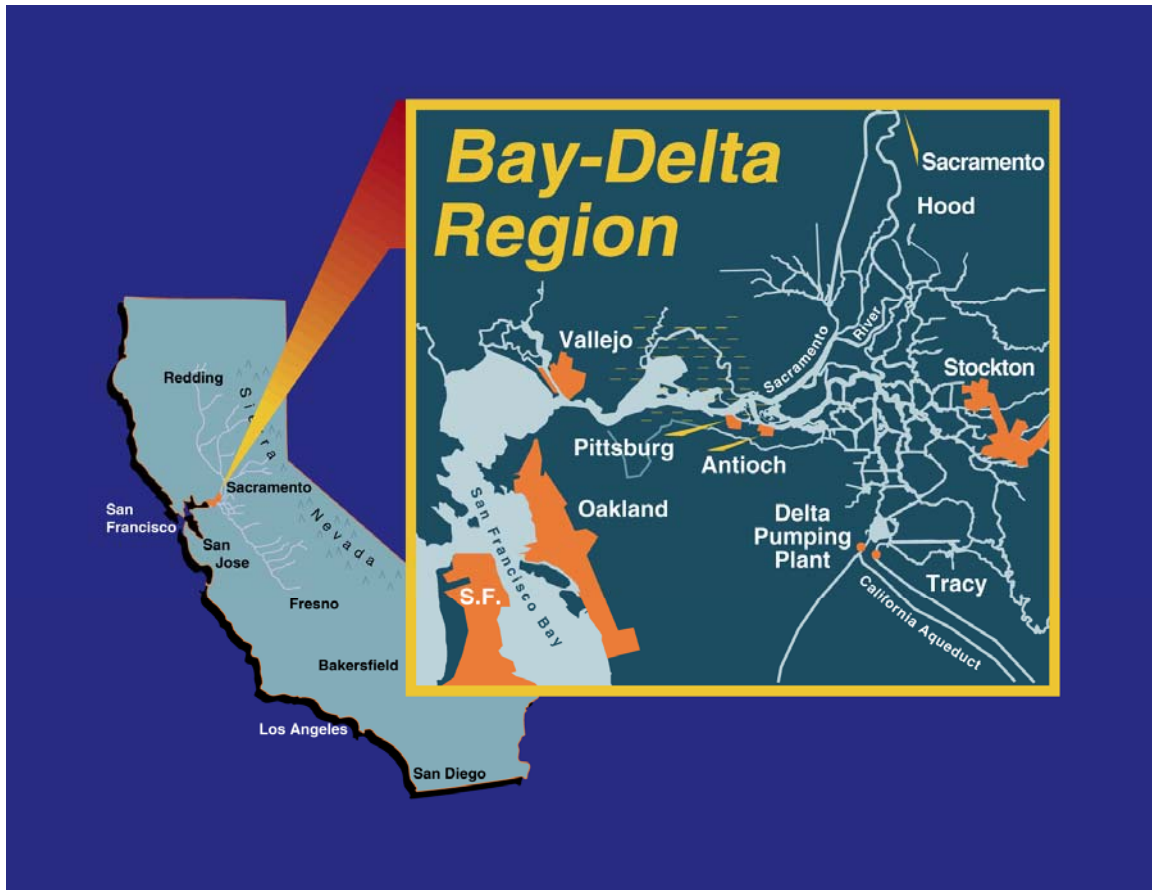
The San Francisco Bay and Sacramento-San Joaquin Delta (Bay-Delta) region (Figure 1) is a highly urbanized and contaminated estuary with a valuable commercial and recreational fishery (Nichlos et al., 1986; SFEI, 2004). Many fish and birds in the San Francisco Estuary exhibit high levels of contaminants (metals and organic pollutants), which have been shown to affect their behavior and reproductive success, yet routes of exposure and assimilation pathways remain unclear. Mercury (Hg) is a contaminant of particular interest because of its prevalence, toxicity, and persistence as an active contaminant in the Bay-Delta and has thus been cited as the greatest threat to the estuary (Domagalski et al., 2001; Rasmussen and Blethrow, 1990).

A number of physiological and behavioral effects on biota have been reported such as the loss of reproductive success due to high metal stress in clams, invertebrates, fish and birds (Brown and Luoma, 1999; Brown et al., 2003; Weiner et al., 2004; Schwartzbach et al., 2005). Many investigations have observed declines in biota contamination in relation to declines in sediment and water concentrations since pollution reduction efforts were instituted (Hornberger et al., 1999), but Hg contamination remains a major problem (Flegal et al., 2004) resulting in consumption advisories in the entire Bay-Delta region (OEHHA, 2005). Understanding the pathways by which contaminants are exposed to and assimilated by biota is essential to appropriately manage Bay-Delta resources and habitats to reduce the threat to the foodweb. The interplay of physical, chemical and biological processes in intertidal habitats provide one potentially significant pathway.

Benthic microorganisms in intertidal zone sediments – diatoms, microalgae, and heterotrophic bacteria – excrete exopolymers that alter the physical properties of the surrounding sediment matrix increasing their effective grain size and nutritive value. These benthic microalgae and their products represent nutritious particulate matter (Decho, 1990; Kneib et al., 1980), and therefore are important participants in nutrient cycles (Hopner and Wonneberger, 1985). Importantly, the exopolymers also are of higher nutritive value than the sedimentary organic material leading to preferential grazing by low trophic biota. These two characteristics result in the exopolymers activating the sediments with respect to biological uptake.

# AN NON-POINT SOURCE OF CONTAMINANTS TO THE ESTUARINE FOOD WEB: MOBILIZED PARTICLES FROM THE INTERTIDAL ZONE

**Figure 1.** The San Francisco Bay and Sacramento-San Joaquin Delta Region.



## **AN NON-POINT SOURCE OF CONTAMINANTS TO THE ESTUARINE FOOD WEB: MOBILIZED PARTICLES FROM THE INTERTIDAL ZONE**

The processes in the intertidal habitats leading to biological activation also activate sediments with respect to contaminant exposure. First, these aggregated sediments have been shown to be elevated in contaminants, particularly metals. Second, the presence of labile organic material in contact with sediments will facilitate the processes that can increase bioavailability, such as partitioning and methylation. Also, highly energetic events – either wind- or rain-storms – are necessary to resuspend the cohesive sediments in these systems, which will preferentially concentrate them spatially and temporally. This could lead to enhanced exposure and assimilation in valuable brooding habitats at an important time for reproduction and maturation.

Understanding where, when, how, and why these processes occur is particularly important to managers and planners in the Bay-Delta region so that the proper preparations can be made for system-wide environmental changes brought on by anticipated (climate change, restoration activities) and unanticipated (earthquakes) events. Therefore, a quantitative understanding of the combined physical, chemical, and biological processes driving local and system-wide biotic contamination is necessary to inform decision makers of future threats and remedial actions available to protect and preserve the Bay-Delta ecosystem.

### **Hypotheses**

We hypothesize that local Bay-Delta weather events facilitate the cycling of Hg sorbed to local intertidal zone sediment, likely reintroducing Hg-contaminated material to the water column and increasing availability to low and high trophic levels. Also, expolymers that bind the surface microlayer of sediment help create highly nutritious but Hg-contaminated flocs. Thus, erosion by rainfall during low tide and wind waves at high tide may activate non-point sources of previously deposited Hg (Torres et al., 2004; Torres and Fulton, submitted). Moreover, the presence of labile organic material in contact with these suficial sediments will facilitate the processes of methylation. Hence, wind- or rainstorms may resuspend contaminated cohesive sediments, and sediment redistribution process may spatially concentrate them, and temporally increase exposure to fauna in spring, an important Bay-Delta time for nursurey habitats that coincides with wind-wave resuspension,

## **AN NON-POINT SOURCE OF CONTAMINANTS TO THE ESTUARINE FOOD WEB: MOBILIZED PARTICLES FROM THE INTERTIDAL ZONE**

We contend that local weather-driven cycling of Hg is a poorly quantified process yet Torres and Fulton (submitted, see below) have demonstrated that physical processes may fractionate sediment and increase metal concentrations above the background levels for two full tidal cycles. Therefore, information on where, when, and why these processes occur are particularly important to managers and planners in the Bay-Delta region, particularly with system-wide environmental changes brought on by anticipated (climate change, restoration activities) and unanticipated (earthquakes) events. A quantitative understanding of the combined physical and biological processes driving local and system-wide biotic contamination is important to inform design and management of tidal marsh restorations and understand future potentialities in San Pablo Bay, Grizzly Bay and fresh water reaches of the Delta.

### **Table 1. Hypotheses and approach**

#### **Background**

Sediments are an important component of the San Francisco Bay estuarine system providing a reservoir of nutritive material that contribute to estuarine productivity (e.g. Hammond and others, 1985). However, much of contamination in the Bay-Delta is bound in sediments derived from upstream mining sources (Van Geen and Luoma, 1999; Alpers and Hunerlach, 200x) and anthropogenic pollution from urban and industrial sources high in toxic substances, such as metals and pesticides, that preferentially adsorb to sediment particles (Kuwabara and others, 1989; Domagalski and Kuivila, 1993, Bergamaschi and others, 1999). The sediments delivered to the Bay-Delta system are often elevated in mercury content but are of relatively poor nutritive value and in a grain-size that is poorly grazed by the macrozooplankton that are consumed by fish and birds. However, algae and bacteria in the intertidal zone alter the physical, chemical, and nutritive properties of sediment that accumulates there.

For instance, biofilms develop on intertidal sediments and they help resist particle motion. Benthic microalgal assemblages consist primarily (~90%) of motile and non-motile diatoms (Pearse, 1977); euglenoids, green algae and cyanobacteria may also be present further helping to stabilize soft sediments (Holland et al., 1974; Paterson et al., 1989). Additional sediment



## **AN NON-POINT SOURCE OF CONTAMINANTS TO THE ESTUARINE FOOD WEB: MOBILIZED PARTICLES FROM THE INTERTIDAL ZONE**

stabilization occurs through binding of sediment particles by exopolymers, produced by motile benthic diatoms (Decho, 1990; Frankel and Mead, 1973; Holland et al., 1974; Paterson 1989), that are capable of rapid movement ( $1\text{--}25\ \mu\text{m s}^{-1}$ ) throughout the upper few millimeters of sediment (Edgar and Pickett-Heaps, 1984; Pinckney et al., 1994). In salt marsh sediments of the southeastern US, ~33% of the total benthic microalgal biomass is in the upper 1 mm, but migration is detectable to depths of 5 mm (Pinckney et al., 1994). This diatom mobility results in the distribution of exopolymers, leading to greater cohesion and most likely, higher critical shear stress. Subsequent sediment dehydration during low tides enhances biogenic cohesion, resulting in increased sediment biostabilization (Paterson et al., 1989).

Episodic weather events (rain and wind) may substantially disrupt the microbial exopolymer-sediment matrix, with subsequent transport of matrix aggregates toward tidal creeks and beyond. These polymer-enriched sediments are more likely to exist as lower-density aggregates when resuspended into the water column, altering their effective grain size and hydrodynamic characteristics thus keeping them in the water column for longer periods of time. This increased suspension time increases the probability for biotic contaminant exposure and assimilation. These disturbance events may also alter recruitment patterns of micro-benthos by changing sediment cohesive properties, exposing subsurface layers, and reducing surficial food quality. Previous work has shown that rainfall-runoff processes introduce material to the water column and thus increase its bioavailability (Mwamba and Torres, 2002, Torres et al, 2003, Torres et al., in press); and may enhance the cycling of benthic microalgae and their products, a primary carbon source for estuarine food webs (Decho, 1990). Episodic weather events that result in physical processes (wind and rainfall) are likely to increase do to changes in the frequency of coastal zone precipitation due to El Niño oscillations, prolonged rainstorms or expected climatic variations (EPA Report, 1998). This would have unknown effects on estuarine material cycling, biogeochemistry, and bioaccumulation in ecologically important shallow water intertidal environments.

Because of the characteristics of these sediments, intertidal physical processes may provide an enhanced pathway for biotic contamination. Torres et al. (2003) have shown that rainfall entrained sediment is compositionally distinct from the bulk composition of the substrate,

## **AN NON-POINT SOURCE OF CONTAMINANTS TO THE ESTUARINE FOOD WEB: MOBILIZED PARTICLES FROM THE INTERTIDAL ZONE**

preferentially entraining particulate matter enriched in organic C and organic N, nutrients essential to very base of the food chain. Moreover, Torres et al. (in prep) report that the concentration of metals in rainfall entrained sediment is 8-14 times greater than the bulk intertidal sediment (Figure 2). The total flux of sediment entrained by low tide rainfall or windwave forces may be low relative to the total sediment budget but may be significant in biotic uptake due to character of particles mobilized by this process. Uptake is a complex process (Luoma et al 1997). Sediments generally need to undergo a change in biogeochemistry to promote biotic uptake. For example, redox interactions may lead to increases in biotic uptake efficiency (Griscom et al. 2000). Also, sediments amended with benthic microalgae increased metal uptake in clams (Lee and Luoma 1998). Finally, sediments amended with fulvic acids were observed to concentrate mercury and increase assimilation in mussels (Gangon and Fisher, 1997).

# AN NON-POINT SOURCE OF CONTAMINANTS TO THE ESTUARINE FOOD WEB: MOBILIZED PARTICLES FROM THE INTERTIDAL ZONE

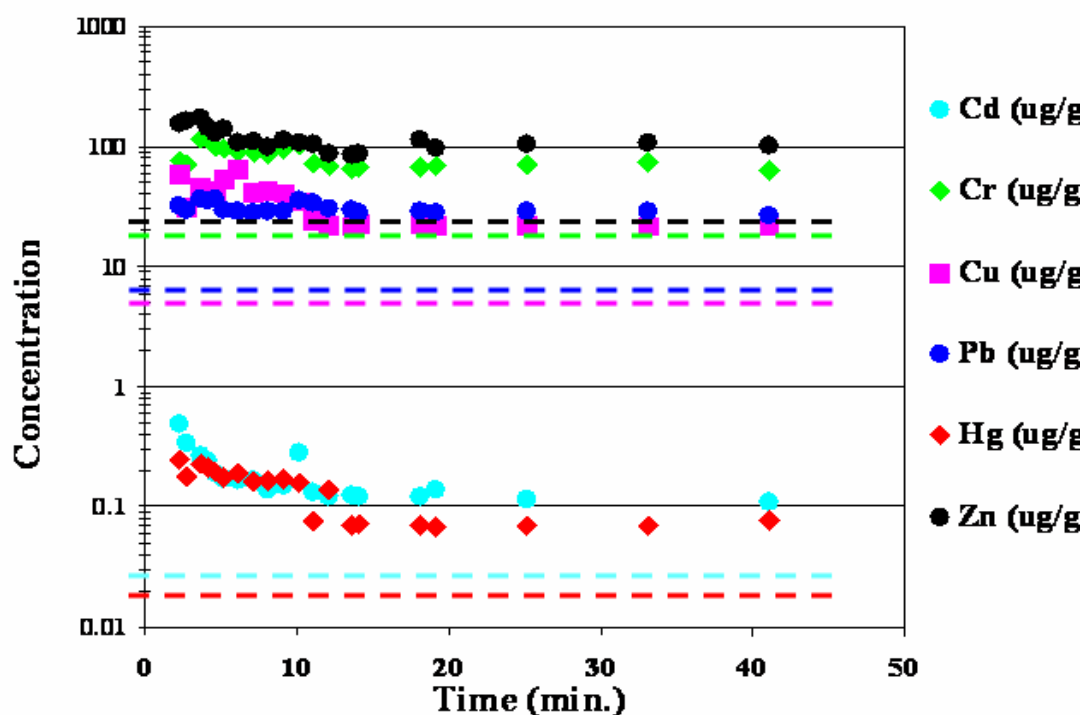


Figure 2. Time series of metal concentrations in sediment transported by rainfall-runoff processes from the experimental salt marsh plots of Torres et al. (2003), and now a part of Torres and Fulton (submitted). Time 0 min refers to the start of the irrigation; end of irrigation was at 45 minutes. The dashed horizontal lines represent background concentrations in sediment. Thus, all samples were elevated relative to background with initially high concentrations that decline with time. The Hg and Cd signals are in the Effects Range Low-Median (after Long et al., 1995) for the first 12 minutes. Thus rainfall-runoff processes preferentially entrain sediment from the upper microlayer leading to unusually high concentration in total suspended sediment samples.

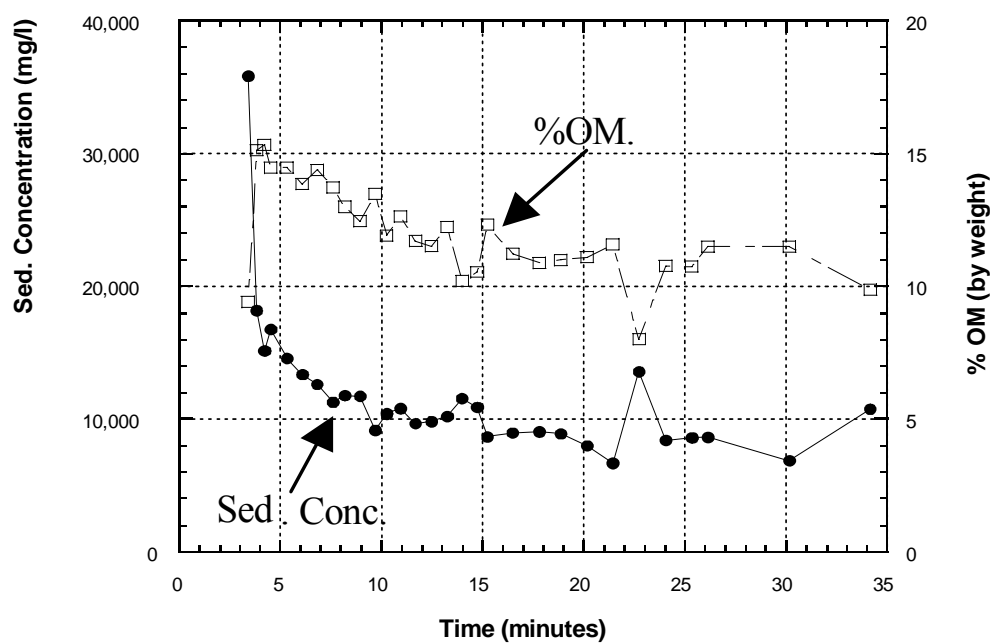
# AN NON-POINT SOURCE OF CONTAMINANTS TO THE ESTUARINE FOOD WEB: MOBILIZED PARTICLES FROM THE INTERTIDAL ZONE

## Previous work related to proposed scope

Mwamba and Torres (2002) conducted several rainfall simulation experiments on 2 m<sup>2</sup> and 3 m<sup>2</sup> salt marsh plots, simulating rainfall events with a 2-10 year recurrence interval. The high marsh produced negligible sediment while the low marsh and channel banks yielded copious amounts. Peak suspended sediment concentrations occurred within 6 minutes of irrigation and ranged from 1500 to 36000 mg/L (Figure 3). After 10-minutes of irrigation the plot suspended sediment concentration was lowered by an average of 0.2 mm, assuming uniform sediment density. More importantly, however, the rainfall-entrained sediments were compositionally distinct from the bulk average substrate (Torres et al., 2003). For example, mobilized sediment was enriched in particulate organic matter (POM), and the bulk chemical composition of mobilized POM differed significantly from the bulk surface sediments, with a factor of ~10 enrichment in nutrient content. These results indicate that rainfall preferentially entrained nitrogen-rich POM (N/C > 0.7), perhaps originating from marine algal sources, leaving behind OM derived from marsh vegetation (Figure 4). Hence, the rainfall-mobilized material had a much higher nutritional quality than the bulk OM of surface sediment. These findings show that low tide rainfall-driven marshland sediment fluxes represent a “non-point source” of OM and nutrients to nearshore ecosystems. On the other hand, recent unpublished findings by Torres et al. (manuscript in preparation) show that the same nutrient rich particulate matter (e.g. OM in the same samples) was enriched in trace metals commonly associated with industrial sources. For example, Cr, Zn, Cu, and Pb were elevated by a factor of 8-14 times above background sediment (Hg was not tested in these samples). Hence, rainfall may preferentially entrain nutrient rich, and metal rich marshland sediment.

These findings lead to the question: *How much material is entrained per storm?* Scaling-up the plot results from North Inlet provides an order of magnitude estimate of 67-120 tons/km<sup>2</sup>, assuming uniform rainfall. This material averaged 10% organic carbon (OC) content (Torres et al., 2003), indicating that 7-12 tons/km<sup>2</sup> of particulate organic carbon (POC) can be mobilized by a single storm. Given a salt marsh area of ~25 km<sup>2</sup> we estimate that 175-300 tons of POC, or 6-10% of the annual POC flux for North Inlet estuary (Dame et al., 1986) may be entrained by a single 10-minute storm. Clearly the potential for rainfall to facilitate substantial POC cycling

# AN NON-POINT SOURCE OF CONTAMINANTS TO THE ESTUARINE FOOD WEB: MOBILIZED PARTICLES FROM THE INTERTIDAL ZONE



**Figure 3.** Time series of sediment concentration and %OM (right axis) versus time. 0=start of rain.

# AN NON-POINT SOURCE OF CONTAMINANTS TO THE ESTUARINE FOOD WEB: MOBILIZED PARTICLES FROM THE INTERTIDAL ZONE

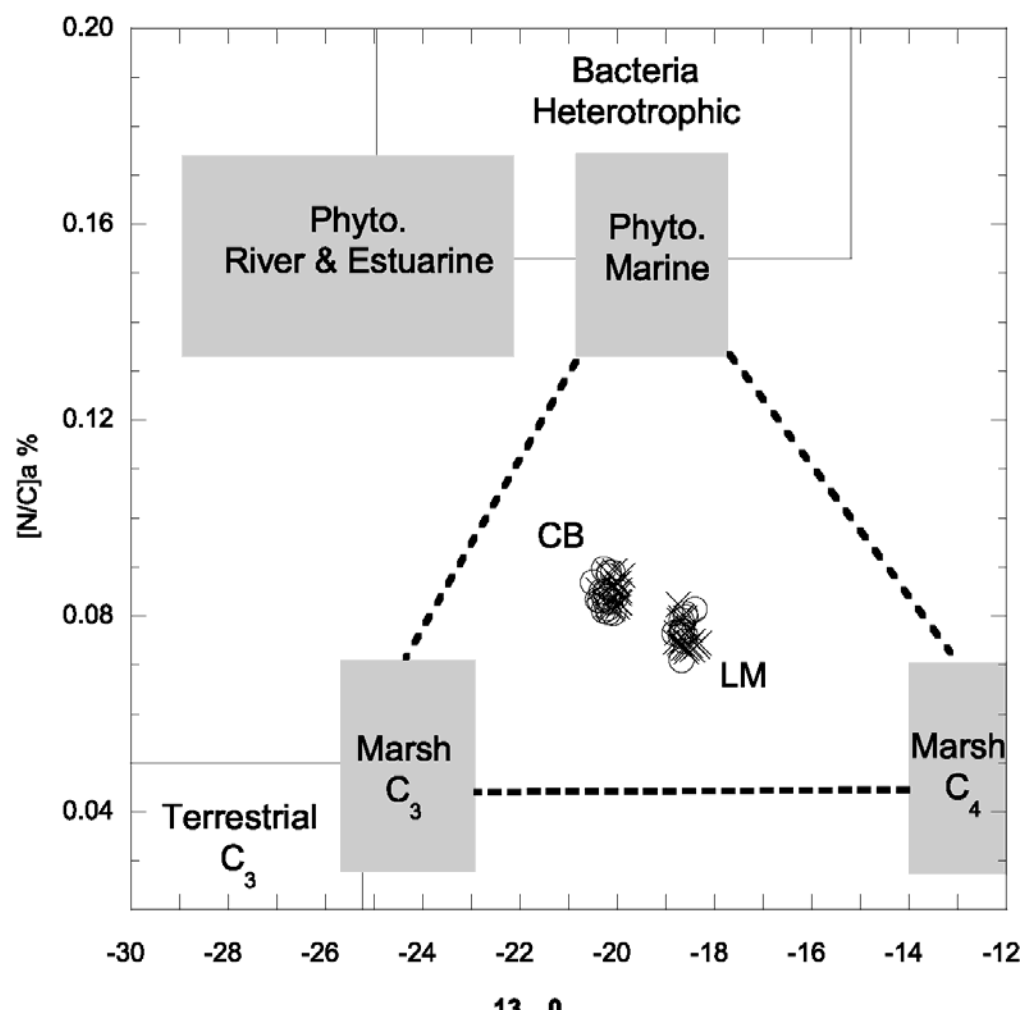


Figure 4. Atomic N/C ratios vs.  $\delta C^{13}$  ‰ showing that the sediment entrained by rainfall has a mixture of  $C_3$  and  $C_4$  plants, and marine microalgae. CB denotes the channel bank cluster of data and LM denotes the low marsh. Cross symbols depict fresh water data and open symbols depict saltwater data. Shaded and open rectangles identify the range of values for various carbon sources.

## **AN NON-POINT SOURCE OF CONTAMINANTS TO THE ESTUARINE FOOD WEB: MOBILIZED PARTICLES FROM THE INTERTIDAL ZONE**

exists but the process is not well defined and is typically absent from biogeochemical cycling models. Here we propose to estimate rainfall-driven sediment yields from Grizzly, Honker and Suisun Bay marshlands.

Of course these are order of magnitude approximations of the process, and much work remains to fully characterize the process. Nevertheless, these observations lead to the question: ***What happens to that rainfall-entrained material?*** Although rainfall events entrain nutritious intertidal material, only a fraction of that sediment may be subject to wider redistribution. For example, velocity and duration of freshwater sheetflow control the delivery of material to the tidal creeks where higher energy flows likely facilitate delivery to the subtidal zone. There wider redistribution or export may occur due to tidal circulation. Hence, the degree to which intertidal creeks dissect the landscape affects sediment redistribution. Analysis of intertidal creek geomorphology gives an average creek drainage density of  $13.1 \text{ km/km}^2$  (Novakowski et al., 2004). Given average sheet flow velocity of 2 cm/sec (Mwamba and Torres, 2002), each minute of rainfall duration leads to a progressively wider swath of marsh delivering sediment-laden water directly to the tidal creek network (Torres et al., in press). Using the estimates of POC mobilization above, freshwater sheet flow velocity and creek network density we estimate that a 4-minute storm delivers 28-48 tons of POC to intertidal channels. This represents 22-40% of the net export of POC from North Inlet during the summer months as reported by Dame et al. (1986), who reasoned that North Inlet estuary is a source of POC to the coastal ocean. Therefore, it appears that during low tide rainfall and runoff processes acting on intertidal marsh and mudflats may have a significant effect on coastal ecosystems by reintroducing nutritious particulate matter to the water column, material that is the primary source of energy in their food webs. Conversely, preliminary data indicate that some of the nutritious particulate matter may be contaminated with metals (Torres et al., in prep.). In the Bay-Delta region, rainfall intensities are not as high as reported above, but it appears that local rainfall events have produced raindrops with sufficient kinetic energy and coverage, to entrain sediment and produce a turbidity response near densely vegetated tidal wetlands (Ruhl and Schoellhamer, 2004). At our study sites, we will map the creek network structure and the local topography around our observation sites to assess the transport of rainfall-entrained sediment.

# **AN NON-POINT SOURCE OF CONTAMINANTS TO THE ESTUARINE FOOD WEB: MOBILIZED PARTICLES FROM THE INTERTIDAL ZONE**

## **Conceptual model**

Episodic weather events may substantially disrupt the nutrient and contaminant enriched microbial exopolymer-sediment matrix, with subsequent transport of matrix aggregates toward the water column. For instance, each raindrop striking the surface can be thought of as a “point source” of momentum loss per area, per time (e.g. Gabet and Dunne, 2004). Pressure exerted by the drop is equal to the rate of momentum loss per area, and equal to the momentum gain by the surface. A soft surface can absorb momentum by consolidation or deformation (e.g., cratering). Also, some of the impact momentum may not be absorbed, but reflected upwards, transporting water and sediment away from the impact site. Ghadiri and Payne (1981, 1988) measured maximum compressive stress of 4.4 MPa that were attributed to a local water hammer effect caused by an initial shock wave. Immediately after impact, the raindrop is deformed and the vertical force is transformed to a lateral shearing force by water jetting over the sedimentary surface (Ghadiri and Payne, 1981). Consequently, these fluid shear stresses, albeit short-lived, may be considered erosive agents, as shown by Hartley and Alonso (1991). Moreover, these shear stresses are typically several orders of magnitude greater than shear stresses that were observed during over-marsh tidal flows (e.g., Christiansen et al., 2000). Hence, more raindrops entrain more sediment, with net transport occurring in a direction determined primarily by the subtle variations in topography and rain obliquity. Since intertidal surface sediments may be at or near saturation very little rainwater goes into subsurface storage. Therefore, runoff may develop shortly after the inception of rainfall. Similar effects would be expected during high energy turbulence that occurs in the water column over shallow intertidal habitats during high wind events. Under these conditions, the strong turbulent forces would break up the cohesive sediments and preferentially entrain enriched sediments according to the same erosive processes that promote particle mobilization in runoff.

The weather events responsible for mobilization also affect carbon cycling and sequestration. Oertel (1976) measured increases in suspended sediment and organic matter concentrations during spring tides and rainstorms, and found that the dissolved organic matter (DOM) fraction had a marsh rather than terrestrial source. Chalmers et al. (1985) measured a net export of organic carbon from a salt marsh during low tide rainstorms. They proposed that rainstorm



## **AN NON-POINT SOURCE OF CONTAMINANTS TO THE ESTUARINE FOOD WEB: MOBILIZED PARTICLES FROM THE INTERTIDAL ZONE**

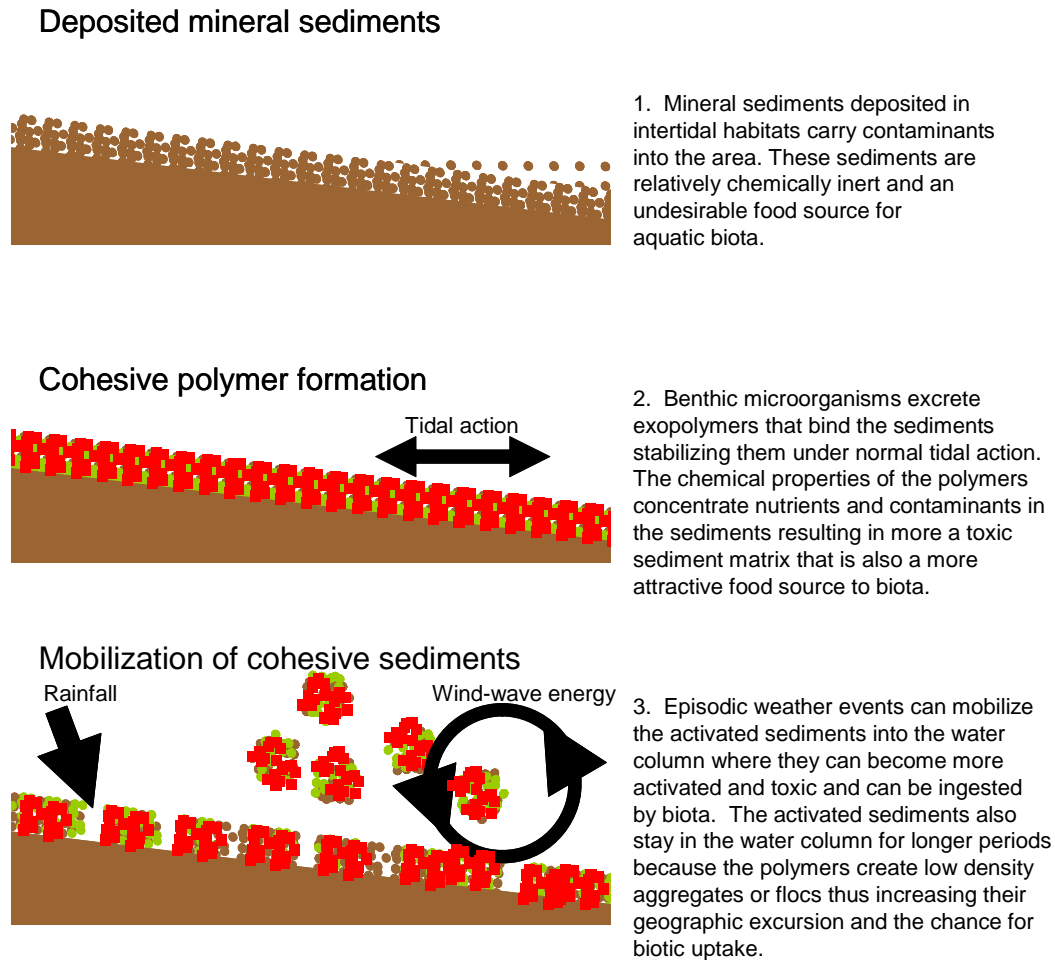
erosion was a vital process that facilitates carbon cycling in salt marshes, affecting OM accumulation and transformation. Also, Dame and Kenny (1986) found that rainfall-induced nutrient redistribution increased primary productivity. Another possible outcome of cohesive sediment dispersal by rainfall may be an overall increase in sediment erodability and concomitant increase in the work done by subsequent tidal currents that prior to rainfall did not entrain sediment.

Wind- and rain-enhanced mobilization of intertidal sediments may intermittently control suspended sediment concentrations observed in marsh channels, mudflats and the entire Bay-Delta system (e.g., Ward, 1981). Higher intensity rain storms provide winds and rain with greater kinetic energy and produce substantial increases of 100-1000 times above background suspended sediment concentration (Settlemyer and Gardner, 1975), and those higher concentrations may persist for several days (Torres et al., in press).

Once mobilized, the enriched particles will be subjected to local hydrodynamic forces. During maximum flood and ebb, low density organic and fine grained particles will be maintained in suspension via normal tidal action. As slack tide approaches, turbulent mixing is greatly reduced and more dense materials will begin to settle out. This sequence of events is repetitive, and the fate of suspended material will depend strongly on the amplitude of the forcing, the point of particle entry in relationship to local habitat geometry and flow stratification due to freshwater runoff. Under average conditions, the enriched particles will likely remain suspended in the water column of the local habitat where contaminants may be concentrated spatially and temporally thus increasing potential biotic exposure and assimilation. Larger amplitude forcing during spring tide produce higher currents and increased particle trajectory range. Therefore, the likelihood of particles leaving the intertidal habitats and entering the greater Bay-Delta system is greater during the greater excursion amplitude of spring tide. Figure 5 represents a simplified version of this model.

# AN NON-POINT SOURCE OF CONTAMINANTS TO THE ESTUARINE FOOD WEB: MOBILIZED PARTICLES FROM THE INTERTIDAL ZONE

**Figure 5.** Conceptual model diagram



# **AN NON-POINT SOURCE OF CONTAMINANTS TO THE ESTUARINE FOOD WEB: MOBILIZED PARTICLES FROM THE INTERTIDAL ZONE**

## **Project Objectives**

- 1) Quantify the relationship between wind and rain intensity and the elevated concentration of aggregated sediments.
- 2) Investigate the extent to which dissolved contaminant concentrations are influenced by resuspension of sediment aggregates containing elevated contaminant concentrations.
- 3) Characterize properties of particle and dissolved constituents that govern elevated contaminant load released through the mobilization process
  - a. Source of particles (benthic polymers, algal, mineral, detrital, etc)
  - b. Particle character (OM content, nutrients, grain and aggregate size)
  - c. Partitioning
- 4) Estimate contribution of this mobilization process on biotic contaminant burden relative to the system background
- 5) Improve our ability to monitor for contaminant transport in restoration and regional settings by developing *in situ* methods for determination of contamination exposure potential using optical characterization of particulate and dissolved constituents.

## **Study Approach**

Ruhl and Schoellhamer (2004) report that large, but short-lived, pulses in turbidity can occur due to episodic weather events. However, it is difficult to decouple the effects of rain and wind on particle mobilization. We intend to look at rain and wind events in winter and spring to decouple the physical processes leading to episodic turbidity events in the Bay-Delta. Winter storms typically include rainfall whereas spring and early summer storms are wind-dominated with little or no associated precipitation ([www.noaa.gov](http://www.noaa.gov)). We will measure the respective contributions of wind and rain events using a field-based approach, employing *in situ* instrumentation capable of measuring suspended sediment concentrations, water flux, and meteorological variables. These physical measurements will provide a means of elucidating which physical processes dominate sediment mobilization at the study sites. We can then compare our local measurements with the

## **AN NON-POINT SOURCE OF CONTAMINANTS TO THE ESTUARINE FOOD WEB: MOBILIZED PARTICLES FROM THE INTERTIDAL ZONE**

established Bay-Delta suspended sediment monitoring network ([www.usgs.gov](http://www.usgs.gov)) to determine the relationship between local observations in intertidal habitats and system-wide turbidity events.

Torres and graduate students will construct a portable sprinkler irrigation apparatus (similar to Torres and Mwamba, 2002) to control the rainfall KE and power, and relate those variables to sediment entrainment, suspended sediment concentration (SSC) and sediment composition. Torres will also monitor and oversee the monitoring of the SSC response to natural rainfall and wind events using OBSs and a Nortek Aquadopp Current Profiler. Also, Torres and students will map topography of the intertidal study areas using an RTK GPS (similar to Torres and Styles, 2006).

We will also characterize the intertidal sediment and porewater properties to those from the substrate sediment and the re-deposited particles. We will determine the organic matter loading of these sediments by measuring the ratios of OC and nitrogen content to mineral surface area (e.g. Mayer, 1994; Mayer et al., 1998). We will use established techniques in our laboratory (e.g., Gordon et al., 2001; Goñi et al. 2003) to investigate the relationships between mineral particle surface area, particle organic loadings, particle density, and particle export. We will also investigate the contrasts in the nature, source, and nutritional quality of the mobilized OM relative to that in the substrate sediment. In order to accomplish this goal, we will use a combination of techniques, including elemental analyses (%carbon, %nitrogen, %biogenic silica), stable isotope analyses ( $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$ ), as well as analyses of lignin, cutin, amino acid and lipid biomarkers (sterols, fatty acids, hydrocarbons). Such a combined approach has been used successfully in previous studies to investigate the composition, sources, turnover, and fate of natural OM in coastal environments (e.g., Benner and Opsahl, 2001; Goñi and Hedges, 1992; 1995; Goñi et al., 2000; 2001; 2003b). Based on these measurements, we anticipate being able to specifically discern the contributions from benthic diatoms, marsh vascular plants, and bacterial sources. For example, benthic diatom contributions will be assessed based on the biogenic silica contents and concentrations of diatom-specific sterols such as brassicasterol (i.e. 24-methylcholesta-5,22-dien-3 $\beta$ -ol). In contrast, we will use the yields of vascular plant-specific compounds such as lignin phenols, cutin acids and long-chain hydrocarbons to identify the

## **AN NON-POINT SOURCE OF CONTAMINANTS TO THE ESTUARINE FOOD WEB: MOBILIZED PARTICLES FROM THE INTERTIDAL ZONE**

contributions from macrophyte vegetation. Furthermore, bacterial contributions will be investigated using specific branched fatty acids uniquely synthesized by microbial organisms.

We will also characterize the particles mobilized from intertidal habitats using chemical and optical methods and compare them to the background sediment. The characterization will determine the presence and relative proportion of high nutrient and high contaminant particles mobilized at the study sites. The optical characterization will be performed using *in situ* instrumentation developed by the USGS capable of measuring absorption, attenuation and scattering of light in the ambient water matrix at a high temporal resolution over the short duration of episodic events. The characterization is performed through coupling high frequency *in situ* measurements of optical properties of water (particle and dissolved) and chemical analyses of discrete samples collected concurrently with the instrument readings. We will then correlate the optical properties to laboratory measurements of biogeochemical properties of the discrete samples to establish a high frequency timeseries of the mobilized particulate and dissolved constituents. The combination of these methods will allow characterization of particles at temporal scale necessary to identify the source of high nutrient, high contaminant constituents in the water column.

We will also investigate the extent to which algal and microbial polymers affect the partitioning of Hg species to the sediments. We will conduct equilibrium dialysis experiments to explore the binding properties of the exopolymers with mercury and other metals. We will also conduct <sup>203</sup>Hg partitioning experiments with suspended sediments eroded under varying climatic conditions in the presence and absence of dissolved organic material to quantify the properties of sediments and other environmental variables that control sorption of MeHg to sediment aggregates.

Finally, we will project the results of these field observations and experiments to the ecosystem scale by developing a regional model of exposure probability. Using the combined parameters of sediment type, bathymetry, wind speed and direction, fetch, light penetration, and intertidal exposure, we will develop a model that predicts the times and locations where significant contaminant exposure may occur. Further, we can estimate the current exposure levels based on

## **AN NON-POINT SOURCE OF CONTAMINANTS TO THE ESTUARINE FOOD WEB: MOBILIZED PARTICLES FROM THE INTERTIDAL ZONE**

ecosystem models (e.g. Sobczak et al.). The hydrodynamic model will provide an estimate of the intertidal habitats that contribute these types of particles and then determine a loading (mass and proportion to total particle load) of these particles to the system under different weather conditions. Results of such a model will help CALFED managers predict the effects of future restorations, levee breaches, and other landscape alterations.

Table 2. Summary of study tasks and responsibilities

	Description	Lead PI	Support	Related objectives
1	Project administration	Torres		All
2	Physical, hydrodynamic and meteorological field measurements	Torres (rain, wind) USGS-CA (wind)	Established monitoring networks	All
3	Laboratory physical and chemical characterization of sediments	Torres (physical) Goni (chemical)	USGS-CA USGS-CO	2 and 3
4	Laboratory physical and chemical characterization of mobilized particles and dissolved constituents	Torres (physical) Goni (chemical)	Torres and USGS-CA (sample collection)	2 and 3
5	Physical, chemical and optical characterization of mobilized particles and dissolved constituents in the field	USGS-CA	Torres (assist sample collection)	1, 2, 3 and 4
6	Partitioning and redox effects on metals cycling	USGS-CO (lab experiments)	USGS-CA (field measurements)	2 and 3
7	Modeling intertidal contributions to system turbidity and biotic contamination	USGS-CA	Torres	4 and 5

### **Supporting information for study approach**

#### ***Site selection***

An ideal study site is one with limited accessibility to help prevent instrument vandalism yet easily accessed by the research team. The ideal site also has some structural considerations. For example, it is desirable to have tidal creeks that retain about 1.5 m of water in an along channel depression. This will prevent the optical sensors from incident sunlight and keep the pumps

## **AN NON-POINT SOURCE OF CONTAMINANTS TO THE ESTUARINE FOOD WEB: MOBILIZED PARTICLES FROM THE INTERTIDAL ZONE**

primed. In some cases it may be necessary to manipulate the substrate slightly for instrument placement.

The selection of locations will also consider including a range of salinities because the contribution of particles and dissolved constituents to biotic contaminant has been reported to be different between fresh and salt water for some metals. Additional considerations will be made for habitat type, representational questions (natural vs restoration/flooded), vegetation differences, and differences in sediment type. We intend to establish four sites that best address the research goals. Current sites being considered: Honker Bay, Grizzly Bay, San Pablo Bay/Napa Restoration combination site, Liberty/Prospect Island (shallow flooded island in tidal range), Big Break, Sherman Lake, and others as they are brought to our attention or additional collaborations present themselves.

### ***Established monitoring networks***

To determine the effects of wind waves, tidal currents, spring/neap cycle, watershed runoff, and other factors that affect suspended-solids concentration (SSC) in San Francisco Bay (Schoellhamer, 1996), a network of eight sites at which SSC is monitored has been established (Buchanan and Schoellhamer, 1996). Optical backscatterance sensors are deployed at two depths at each site, and measurements are automatically collected every 15 minutes. Water samples are collected periodically and analyzed for SSC, and the results of these analyses are used to calibrate the sensors. In addition to the continuous monitoring sites, which are located in relatively deep water (greater than 10 meters), instrument packages that measure current velocity, water depth, SSC, and wave properties have been deployed in relatively shallow waters (about 3 meters) of the Bay for periods of several weeks (Buchanan and others, 1996).

# AN NON-POINT SOURCE OF CONTAMINANTS TO THE ESTUARINE FOOD WEB: MOBILIZED PARTICLES FROM THE INTERTIDAL ZONE

## *Field methods/instrumentation*

<u>Measurement</u>	<b>Purpose for Measurement</b>	<b>Instrumentation</b>	<b>Reference</b>
<i>in situ</i> suspended sediment concentration	Measure the concentration of particles in water during background and episodic events	OBS, Reading will be taken at 1 Hz for 30 seconds every 15 minutes	Torres et al. 2003
Water velocity	Measure water movement and in combination with tidegauge we can measure water flux	Sontek 8000 current meter	Torres et al. 2003
Water depth	Used to determine water flux	Tidegauge, Global Water Inc, Level Logger	Torres et al. 2003
Wind speed and direction	Helps determine role of wind speed and direction on episodic mobilization of particles in Bay-Delta habitats and main-stem channels	Campbell Sci Windsonic-L 2-D Sonic Wind Sensor	Campbell Scientific
Precipitation intensity and duration	Helps determine role of rainfall on episodic mobilization of particles in Bay-Delta habitats and main-stem channels	Texas Instruments, model T110 capable of measuring rainfall at 2-minute intervals	Torres et al. 2003
Waves and Tides	Measurement of wave amplitude and tide intervals provides information about tidal action and turbulence caused by wind events	<b><u>SEAGAUGE Wave &amp; Tide Recorder (SBE 26plus) Sea-Bird Electronics, Bellevue, WA</u></b>	Burau et.al. 1998 Bishop and Donelan, 1987
Mudflat/marsh sediment collection	Samples will be taken to the lab to help characterize undisturbed sediment	Petri dishes pushed into sediment surface and processes in lab	Torres et al. 2003
Sediment porewater collection	Samples will be taken to the lab to help determine pore-water characteristics in undisturbed sediments	Composited ring cores (4" diameter, 1" thick) collected by hand into 500 mL jars followed by lab centrifugation	Marvin-DiPasquale, 2003
Bulk water suspended sediments collection	Samples will be taken to the lab to help characterize suspended sediment	Pump and filter, through Whatman #1557...	Method 1669 (USEPA, 1996) for trace metals, and methods 625 (USEPA, 1984) and 846 (USEPA, 1986) for organic geochemical analyses



# AN NON-POINT SOURCE OF CONTAMINANTS TO THE ESTUARINE FOOD WEB: MOBILIZED PARTICLES FROM THE INTERTIDAL ZONE

<u>Measurement</u>	<b>Purpose for Measurement</b>	<b>Instrumentation</b>	<b>Reference</b>
Bulk water calibration sample collection	Calibration of optical instrumentation	USGS D-77 sampler equipped with clean Teflon bottle and 1/4" nozzle	Ganju et al. 2005  Edwards and Glysson, 1999
<i>in situ</i> temperature	Rates of microbial activity and abiotic chemical reactions are typically positively related to temperature	Direct on-site measurement with DS-4 CTD	Hydrolab, 1998
<i>in situ</i> specific conductance	This parameter is a function of dissolved cations and anions in solution (e.g. ionic strength), which can impact the dissolved/particulate partitioning in unfiltered water. This can ultimately impact contaminant uptake into the food web.	Direct on-site measurement with DS-4 CTD	Hydrolab, 1998
<i>in situ</i> pH	This parameter is a function of the hydrogen (H <sup>+</sup> ) ion concentration in solution, which can impact the dissolved/particulate partitioning of Hg in unfiltered water. This can ultimately impact contaminant uptake into the food web.	Direct on-site measurement with DS-4 CTD equipped with a pH probe	Hydrolab, 1998
<i>in situ</i> Dissolved Oxygen (D.O.)	Low D.O. water is indicative of high rates of anaerobic microbial activity, a condition that can enhance metal partitioning and MeHg production.	Direct on-site measurement with Aandera dissolved O <sub>2</sub> meter	www.Aandera.com

# AN NON-POINT SOURCE OF CONTAMINANTS TO THE ESTUARINE FOOD WEB: MOBILIZED PARTICLES FROM THE INTERTIDAL ZONE

<u>Measurement</u>	<b>Purpose for Measurement</b>	<b>Instrumentation</b>	<b>Reference</b>
<i>in situ</i> optical properties of dissolved constituents	Provides information about DOM character (ie: hydrophobicity, aromaticity, reactivity, composition, etc) which may aid in understanding Hg-DOM interactions, OM decomposition, photoexposure of water, and a suite of other parameters affecting elemental cycling	filter at 0.2 um – scan for optical absorption over 200-700 nm (ISUS spectra-photometer), absorbtion and attenuation from 400-700nm (AC-9 spectra-photometer), and fluorescence of 370/460 nm exitation-emission pair (CDOM)	ISUS: Johnson and Colletti, 2003  AC-9: Twardowski et al., 1999 Twardowski and Donaghey, 2001  Fluorescence: Coble 1996; Coble et al. 1993; Bergamaschi et al. 2005
<i>in situ</i> optical properties of particles	Provides information about particle character (ie: particle size distributions, source, reactivity, composition, etc) which may aid in understanding metals and nutrient cycling	Unfiltered and filtered (0.2um) channels of AC-9 spectra-photometer followed by spectral slope and shape analysis	Particle size distribution: Twardowski et al. 2001  Particle source/composition: Boss and Zaneveld, 2003

# AN NON-POINT SOURCE OF CONTAMINANTS TO THE ESTUARINE FOOD WEB: MOBILIZED PARTICLES FROM THE INTERTIDAL ZONE

## *Laboratory methods*

<u>Matrix - Parameter</u>	<b>Purpose for Measurement</b>	<b>Analytical Method</b>	<b>Reference</b>
Sediment – Total Mercury (HgT)	Mercury is a toxic element of concern that bioaccumulates in aquatic food webs.	Microwave assisted sample digestion in hot concentrated acid → oxidation to Hg(II) → reduction to elemental Hg <sup>0</sup> with SnCl <sub>2</sub> → trapped on gold covered sand → quantified via CVAFS	Olund et al. 2004, Vazquez et al. 1997, <a href="http://www.frontiergeoscience.com">www.frontiergeoscience.com</a>
Sediment – Methylmercury ( <b>MeHg</b> )	The form of mercury, which is most toxic, which most readily bioaccumulates up aquatic food webs, and which is produced by bacteria in sediments.	Distillation → aqueous phase ethylation → GC separation → pyrolyzation → quantification via CVAFS	DeWild et al. 2004  <a href="http://www.frontiergeoscience.com">www.frontiergeoscience.com</a>
Sediment and suspended sediment - Metals: Cd, Cu, Cr, Pb, As and Zn	Metal contamination has been shown to be a stress on biotic success in the system due to its transfer into the foodweb	standard ICP-MS protocol for trace metals in sediment	<a href="http://www.frontiergeoscience.com">www.frontiergeoscience.com</a>
Sediment - Biogenic silica	Measurement of benthic diatom contributions to sediment matrix		Mortlock and Froelich, 1989
Sediment - Biomarkers - lignin, cutin, amino acid and sterols	Help determine composition, sources, turnover, and fate of natural OM in coastal environments	automated on-line combustion followed by continuous flow isotope ratio mass-spectrometry on a Finnigan Delta-XLS Plus mass spectrometer	Benner and Opsahl, 2001;  Goñi and Hedges, 1992; 1995;  Goñi et al., 2000; 2001; 2003b  Goni et al., 2003
Sediment (and SS?) - Polycyclic Aromatic Hydrocarbons (PAHs)	PAHs are one of the major organic contaminants in the system	Varian CP-3800 GC linked to a Varian Saturn 2000 Ion-Trap mass spectrometers (GC-ITMS)	Teixeira, M. 2000. US EPA methods 625, 3550, 3640 and 8270
Sediment and SS - organic content (ON, OC, OM)	Provides information on particle character that affects nutrient and contaminant levels and likelihood of biotic uptake	Combustion of dried and homogenized sediment at elevated temperature (~1000 °C) on a Thermoquest Elemental Analyzer	Goni et al., 2003  Goni and Hedges, 1995

# AN NON-POINT SOURCE OF CONTAMINANTS TO THE ESTUARINE FOOD WEB: MOBILIZED PARTICLES FROM THE INTERTIDAL ZONE

<u>Matrix - Parameter</u>	<b>Purpose for Measurement</b>	<b>Analytical Method</b>	<b>Reference</b>
Sediment and SS - Stable isotopic compositions of organic carbon and total nitrogen	Help determine composition, sources, turnover, and fate of natural OM in coastal environments	automated on-line combustion followed by continuous flow isotope ratio mass-spectrometry on a Finnigan Delta-XLS Plus mass spectrometer	Goni et al., 2003
Sediment - sample volume, bulk density, particle density, Mineral particle surface area, sample volume	physical characteristics that affect other measurements and help explain mobilization and reactivity	Horiba Laser Particle Analyzer, Dynac pycnometer	Gordon et al. 2001  Goni et al. 2003
Sediment - Pore Water - Dissolved organic carbon (DOC)	May complex various metals, may mobilize mineral sediment contaminants, indicator of relative organic substrate available to fuel heterotrophic bacteria Sediment characterization parameter. May influence contaminant bioavailability	Pore-water collection via centrifugation (anoxic) → pore-water filtration (0.45 μm) → high temperature non-catalytic oxidation with IR detection pH electrode placed directly into sediment	Method: Bird et al. 2003  Purpose: Driscoll et al. 1995, Reddy and Aiken. 2001 USEPA 1996. Method 9040
Bulk water - Dissolved organic carbon (DOC)	May complex various metals, may mobilize mineral sediment contaminants, indicator of relative organic substrate available to fuel heterotrophic bacteria Sediment characterization parameter. May influence contaminant bioavailability	Collection via USGS DOC protocols → chilled on wet ice for preservation → filtration (0.70 μm, quartz fiber filter) within 24hrs → high temperature non-catalytic oxidation with IR detection Pore-water collection via centrifugation (anoxic) → pore-water filtration (0.45 μm) → high temperature non-catalytic oxidation with IR detection	Method: Bird et al. 2003  Purpose: Driscoll et al. 1995; Reddy and Aiken. 2001 Method: Bird et al. 2003  Purpose: Driscoll et al. 1995, Reddy and Aiken. 2001
Bulk water – Unfiltered total mercury (U-HgT)	Largely particle-associated, spatial and temporal variation in U-HgT reflects physical transport processes that move Hg throughout the system.	Trace-metal-clean sample collection protocols are employed → acidified with HCl for preservation → all Hg converted to Hg(II) using BrCl → SnCl <sub>2</sub> reduction → gold-sand trapping of Hg <sup>0</sup> → quantification via CVAFS	Gill and Fitzgerald 1987; Olson and DeWild 1999

# AN NON-POINT SOURCE OF CONTAMINANTS TO THE ESTUARINE FOOD WEB: MOBILIZED PARTICLES FROM THE INTERTIDAL ZONE

<u>Matrix - Parameter</u>	<b>Purpose for Measurement</b>	<b>Analytical Method</b>	<b>Reference</b>
Bulk water – Unfiltered methylmercury (U-MeHg)	The presence of appreciable U-MeHg suggests MeHg flux from the sediment to the bulk water, where it is taken up into the base of the pelagic food web. This parameter often represents the Hg-species that is most strongly correlated with variations Hg in biota	Same as above	Olson and DeWild 1999, DeWild et al. 2002
Bulk water – Filtered total mercury (F-HgT)	The fraction of total mercury that passes through a 0.45 µm filter may be more reactive and susceptible to methylation and complexation by DOC than the overall mercury in unfiltered water.	Filtration (0.45 µm) → Same as U-HgT Trace-metal-clean sample collection protocols are employed → acidified with HCl for preservation → aqueous phase ethylation → GC separation → CVAFS detection	Gill and Fitzgerald 1987; Olson and DeWild 1999
Bulk water – Filtered methylmercury (F-MeHg)	The fraction of methylmercury that passes through a 0.45 µm filter may be more reactive and susceptible to bioaccumulation and interaction with DOC than the overall methylmercury in unfiltered water.	Same as above	Same as above
Bulk water – optical properties of dissolved constituents	Used to calibrate <i>in situ</i> field instrumentation  Lab instruments provide more information than field instruments	filter at 0.2 µm – scan for optical absorption and fluorescence over 200-700 nm wavelengths at 1nm interval and 8000 excitation-emission pairs	UV Absorbance: Ogura and Hanya 1966; Weishar et al. 2003;  Fluorescence: Coble 1996; Coble et al. 1993
Sediment partitioning	Determine partitioning of Hg species to sediments	Radiotracer partitioning.	e.g. Pickhardt et al. (2002); Gagnon and Fisher (1997)
Binding of metals and mercury to microbial and algal exopolymers.	Determine partitioning of metals and mercury to exopolymers.	Equilibrium dialysis	Haitzer et al. (2003)
Competition of dissolved organic material with sediment binding.	Determine partitioning of Hg species to sediments in the presence of DOM	Radiotracer partitioning.	e.g. Pickhardt et al. (2002); Gagnon and Fisher (1997)

# **AN NON-POINT SOURCE OF CONTAMINANTS TO THE ESTUARINE FOOD WEB: MOBILIZED PARTICLES FROM THE INTERTIDAL ZONE**

## ***Data analyses***

Variables controlling turbidity in the Bay-Delta system are related to river discharge, wind speed and direction, water currents, rain intensity and duration, land use activities and migration of the turbidity maximum zone. We will make use of prefiltered and filtered OBS data to evaluate the nature of changes in turbidity. For example, extant discharge, current, wind and rain data will be combined with the OBS signal in a Matlab environment. All in situ optical measurements will be similarly merged and binned at the frequency of the lowest frequency sampling instrument. A master merged file database will be created and stored according to USGS data security requirements. Statistical relationships between field and laboratory data will be explored. These relationships will be used to generate high frequency timeseries of biogeochemical data during the episodic events measured during the deployments. The timeseries will be analyzed with first and second derivatives to ascertain the nature of increases compared to the controlling variables. These same procedures were used by Torres and Alexander (2002) to evaluate timing of changes in hydrologic systems.

## ***Data storage and deliverables***

Data acquired from other sources will be archived as part of this project. Data from project-specific sensors will be acquired in coordination with established monitoring efforts, but adjusted to GMT to avoid complications associated with day light savings time changes. Readings of all instruments will be taken at 15-minute intervals except optical characterization sensors, which will sample continuously during episodic events. The tipping bucket rain gage will count pulses and store 2-minute totals. Data from all sensors will be downloaded and evaluated for problems associated with single value voltage spikes. This will partly be addressed by sampling protocol for the tide gage, OBS and current and data storage. Readings will be taken at 1 Hz for 30 seconds every 15 minutes. We will program the sensor to calculate and store the mean, SD and variance. This smoothing approach will preclude the global removal of the large spikes in SSC that are of interest in this study, and the SD and variance will shed light on the nature of these signals.

In the process of analyzing the data we anticipate making power point presentations at professional society meetings and to interested government and non-government agencies, as

# AN NON-POINT SOURCE OF CONTAMINANTS TO THE ESTUARINE FOOD WEB: MOBILIZED PARTICLES FROM THE INTERTIDAL ZONE

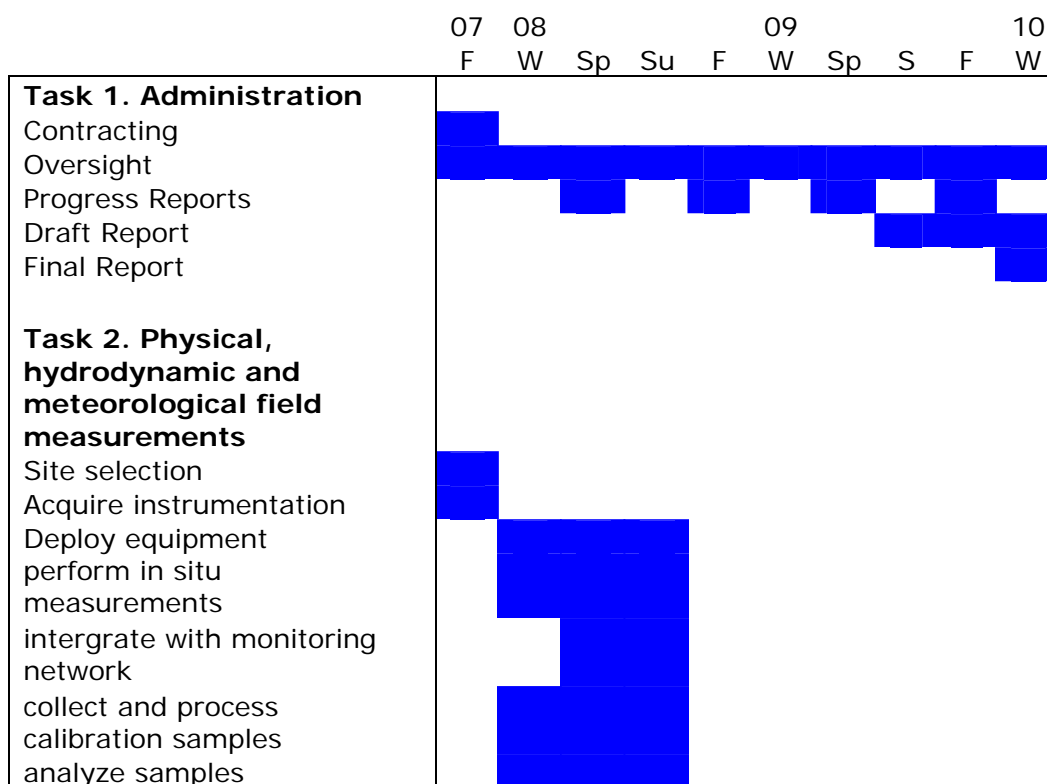
well as stakeholder organizations and other public groups with interest in environmental and water issues. We will maintain a web site with pictures and graphs designed for scientists and the general public. The web site will have power point presentations for downloading and the data will be uploaded after QA and QC.

Likely peer-reviewed publications or formal presentations will have titles such as:

- 1) Geochemical composition of episodic weather-driven particulate matter (with temporal considerations).
- 2) Sources of surface OM in marsh landscapes of the Suisun Bay delta.
- 3) Weather-driven trace metal cycling in marshlands.
- 4) Contribution of episodic events to suspended sediment and dissolved contamination in the Bay-Delta

And others as the picture becomes more complete with refined analyses and discussion with other scientists.

## ***Timeline***



# AN NON-POINT SOURCE OF CONTAMINANTS TO THE ESTUARINE FOOD WEB: MOBILIZED PARTICLES FROM THE INTERTIDAL ZONE

<p>establish in database</p> <p>data analyses</p> <p>statistical analyses</p> <p>draft JA</p>	
<p><b>Task 3. Laboratory physical and chemical characterization of sediments</b></p> <p>collect and process samples</p> <p>conduct lab analyses</p> <p>data analyses</p> <p>intergrate with suspended sediment data</p>	
<p><b>Task 4. Laboratory physical and chemical characterization of mobilized particles and dissolved constituents</b></p> <p>collect and process samples</p> <p>conduct lab analyses</p> <p>data analyses</p> <p>integrate with in situ measurements</p>	
<p><b>Task 5. Physical, chemical and optical characterization of mobilized particles and dissolved constituents in the field</b></p> <p>Acquire instrumentation</p> <p>Deploy equipment</p> <p>perform in situ measurements</p> <p>collect and process calibration samples</p> <p>analyze samples</p> <p>establish in database</p> <p>data analyses</p> <p>statistical analyses of timeseries and correlations</p> <p>draft JA</p>	



# AN NON-POINT SOURCE OF CONTAMINANTS TO THE ESTUARINE FOOD WEB: MOBILIZED PARTICLES FROM THE INTERTIDAL ZONE

### Task 6. Partitioning and redox effects on metals cycling

- collect and process samples
- for lab experiments
- setup experiments

- analyze samples
- establish in database
- data analyses
- statistical analyses of timeseries and correlations in relation to partitioning and redox

draft JA

## Task 7. Modeling intertidal contributions to system turbidity and biotic contamination

- obtain all required data
- setup turbidity model parameters
- set up ecological model parameters
- Run model scenarios
- analyze results
- draft report

# **AN NON-POINT SOURCE OF CONTAMINANTS TO THE ESTUARINE FOOD WEB: MOBILIZED PARTICLES FROM THE INTERTIDAL ZONE**

## **Feasibility**

The project's stated objectives are consistent with the scope of work presented. The measurements performed in the field and laboratories are effective and have been utilized in previous research. The greatest challenge will be in the development of the ecological model and selection of appropriate assumptions. The breadth of this interdisciplinary project is a challenge but the use of collaborative data and information sharing will greatly aid in the completion of this task where the measurements are lacking.

Weather will not threaten the completion of this research as we intend to sample common Delta conditions that occur in all years. Large rainfall events are preferred but not necessary and even in dry years there are sufficient rainfall events to serve our needs. Moreover, Torres' rainfall simulator will augment all natural storm observations. Wind events are common in the region (e.g. Ruhl and Schoelhammer, 2004) and we do not foresee any problems with assessing the effects of wind waves on sediment entrainment. Of course large signals are favorable to the study objectives and will be exploited as the opportunity arises. Thus our proximity to the study area facilitates a rapid response.

No permitting is required for this work although permission for access and use may be required for some study locations. However, we have had wide support in the region from landowners and managers in the past and do not foresee any undue impediment to our work due to denial of access. Site selection has yet to be finalized and this will be one criterion upon which the sites are chosen.

This research is directly related to priority research topic 4, addressing the need for research that expands our "understanding of the effects of anticipated changes (climate change and resource use/restoration plans) and unanticipated changes (earthquakes) on habitats and communities of key species and the potential for remedial action" as stated in the PSP. This project addresses a number of the underlying abiotic drivers (salinity, depth, hydrologic regimes, turbidity, contaminants) that affect habitats and key species listed in the PSP. Specifically, the project

## **AN NON-POINT SOURCE OF CONTAMINANTS TO THE ESTUARINE FOOD WEB: MOBILIZED PARTICLES FROM THE INTERTIDAL ZONE**

investigates the physical and geochemical processes that lead to contaminant mobilization and transfer to the foodweb from intertidal habitats, a necessary component to modeling future scenarios under changing environment. These processes can be used in both plan/design actions such as restoration projects and natural progressions such as sea-level rise and changes in flow and precipitation patterns. These processes are the primary drivers in all geographic regions of the Bay-Delta region making the study results applicable throughout the system. Because this research is based on underlying processes and mechanisms, models can be constructed to predict effects of potential scenarios, both to address restoration planning/design and forecast effects of system changes. The model developed as part of this project will also assess current intertidal habitat extent and explore scenarios under environmental change due to human activities and natural trends.

This research is also directly related to the priorities outlined in section II of this PSP promoting interdisciplinary research and collaborations, the use of established monitoring networks and projects, and the use of an interdisciplinary modeling approach to connect physical, chemical and ecological processes to system-level responses. The investigators on this project also will provide a significant amount of match to offset the cost of the research to CALFED. This will be attained through no-cost equipment use, in-kind services and salaries from federally funded collaborators, the acquisition of Federal Matching Funds, and the use of established monitoring networks and collaboration with the people and organizations that maintain them.

In addition, this research fulfills CALFED issues not addressed in this PSP including the Mercury Strategy and the Pelagic Organism Decline assessment. Furthermore, the project compliments other current and past research in the Bay-Delta investigating mercury contamination, transport and bioaccumulation (Stephenson et al., Foe et al., Marvin-DiPasquale et al., Bergamaschi et al., Slotten et al., Davis et al.); organic matter sources, transport and cycling (Bergamaschi et al., Cloern et al., Sobczak et al.); and metals (Luoma et al., Jassby et al.).

### **Staff Qualifications**

## **AN NON-POINT SOURCE OF CONTAMINANTS TO THE ESTUARINE FOOD WEB: MOBILIZED PARTICLES FROM THE INTERTIDAL ZONE**

Torres is an associate professor at the University of South Carolina conducting research and teaching courses in intertidal zone sediment mobility, geomorphology and surface processes.

Torres has a strong grant and publication related to these topic showing the effects of rainfall in terms of sediment transport, nutritional quality, and the concentration of metals (see References section and CV) and on the geomorphic evolution of intertidal landscapes. Torres has a publication record with Goni, where they collaborated on a study to reveal organic carbon properties of intertidal sediment.

Goni is an associate professor at the University of Oregon where his research is focused on the coastal and deep ocean organic carbon cycling. Recent work has been focused on carbon labile carbon in intertidal landscapes. Goni has a clean carbon isotope geochemistry laboratory with state-of-the-art equipment from which numerous data sets have emerged and led to publications in GCA, Nature, L&O and others (see CV).

Frontier Geoscience is a leading metal analysis laboratory with a set of highly regarded analytical standards. The company is an advanced research and analytical laboratory specializing in the characterization and determination of trace metals in various environments using state-of-the-art equipment. For more information see the appended information detailing the QA and QC protocols that facilitate high accuracy and high precision analyses of trace metals, including mercury and methylated mercury.

The USGS California Water Research Center in Sacramento is well-established research center with modern research facilities and staff expertise that spans over the environmental sciences. The staff involved with this proposal has extensive experience in biogeochemical cycling in tidal systems and has been involved in a number of previous and ongoing combination field and laboratory projects in the Bay-Delta (see attached CVs).

# **AN NON-POINT SOURCE OF CONTAMINANTS TO THE ESTUARINE FOOD WEB: MOBILIZED PARTICLES FROM THE INTERTIDAL ZONE**

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## Raymond Torres

Associate Professor

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### **EDUCATION**

Ph.D. Geology	1997,	University of California, Berkeley
B.A. Geological Sciences	1990,	University of California, Santa Barbara

### **EMPLOYMENT**

2004-present	University of South Carolina, Associate Professor
1998-2003	University of South Carolina, Assistant Professor
1990-1997	University of California, Berkeley, Research Assistant
1988-1989	California Coastal Commission, Program Analyst
1986-1988	T.A.F. Well Drilling Company, Maseru, Lesotho, Manager
1984-1986	Peace Corps, Leribe, Lesotho, Rangeland Management Technician
1982-1984	Intern with the USFS, Los Padres National Forest, Hydrology Technician,

### **PUBLICATIONS**

#### **Peer-Reviewed**

- Torres, R, S Fagherazzi, D vanProosdij, C Hopkinson, Introduction to the Special Issue on Salt Marsh Geomorphology, *Estuarine Coastal and Shelf Science* (in press)..
- Torres, R., R. Styles, Effects of Topography on Salt Marsh Currents, *Journal of Geophysical Research-Earth Surface* (in press).
- Tymchak M.P., R. Torres, Effects of Rainfall Intensity Variations on the Unsaturated Zone Response of a Forested, Sandy Hillslope, *Water Resources Research* (in press).
- Julian, J.P., R. Torres, Hydraulic Erosion of Cohesive River Banks, Sand River, SC, *Geomorphology*, 76, doi:10.1016/j.geomorph.2005.11.003, 2006.
- Montane, J.M., R. Torres, Accuracy and Precision of LiDAR in a Salt Marsh, *Photogrammetric Engineering and Remote Sensing*, 72(8), 961-972, 2006.
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- Mwamba, M.J., R. Torres, Rainfall Effects on Marsh Sediment Redistribution, *Marine Geology* 189, 267-287, 2002.
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- Anderson, S.P., W.E. Dietrich, R. Torres, D.R. Montgomery, K. Loague, Concentration-discharge Relationships in Runoff from a Steep, Unchanneled Catchment, *Water Resources Research*, 33(1) 211, 1998.
- Anderson, S.P., W.E. Dietrich, D.R. Montgomery, R. Torres, M.E. Conrad, K.M. Loague, Subsurface Flow Paths Through a Steep Unchanneled Catchment, *Water Resources Research*, 33(12) 2637-2641, 1998.

### Submitted

- Fornwalt, B., R. Torres, J.T. Morris, Topographic Effects on Subsurface Flow Paths Through Riparian Buffers, *Journal of Environmental Quality*, resubmitted, (Fornwalt is an undergraduate).
- Tymchak, M.P., R. Torres, Soil-water Dynamics Around a Pocosin Wetland in Wind-blown Sand – *Vadose Zone Journal*.
- Torres R., W.E. Dietrich, Dynamics of Lateral Unsaturated Flow Paths in Steep Unchanneled Valley, *Water Resources Research*.

### Pending or in prep.

- Zhou X., R. Torres, Topographic Analyses of an Intertidal Landscape, *JGR-ES*.
- Torres, R., W.E. Dietrich, Soil-water Content Dynamics of a Steep, Unchanneled Valley, *WRR*.
- Torres, R., R. Fulton, Low Tide Rainfall-driven Contaminant Cycling, *ECSS*.
- M. Dawson, R. Torres, Neural Network Analyses of Oyster Distributions in Tidal Creeks, *Estuaries*.
- Torres R., R. Pestrong, J. Callaway, A Comparison of Tidal Creek Geometry Over a 60-year Interval, San Francisco Bay, California.

### Invited abstracts

- Torres, R., Geomorphology of Intertidal Zone Landscapes: North Inlet, SC, Estuarine Research Federation, Norfolk, VA, October 15-19, 2005.
- Torres, R., Goni, M.A., Properties of Intertidal Sediment Mobilized by Rainfall, ASLO Summer Meeting, Savannah, GA, 2004.
- Torres, R., M.J. Mwamba, Rainfall Erosion of a Salt Marsh, AGU Spring Meeting, *EOS Transactions AGU*, 83(22), Fall Meeting Supplement, 2002.
- Torres, R., W.E. Dietrich, D.R. Montgomery, S.P. Anderson, K. Loague, Unsaturated-saturated Zone Interactions in a Steep Unchanneled Valley, AGU Chapman Conference on State of the Art Hillslope Hydrology, Sun River Oregon, October, 2001.
- Montgomery, D.R., W.E. Dietrich, R. Torres, S.P. Anderson, K. Loague, The Coos Bay Experiments: Water Movement on Steep Hillslopes, AGU Chapman Conference on State of the Art Hillslope Hydrology, Sun River Oregon, October, 2001.
- Torres, R., W.E. Dietrich, D.R. Montgomery, S.P. Anderson, K. Loague, How Does the Unsaturated Zone Deliver Water to Saturated Zone Fast Enough to Induce Slope Instability? *EOS Transactions AGU*, 79(22), Spring Meeting Supplement, 1998.

and 28 more contributed abstracts.

### Books

- Laboratory Manual: Exercises in Environmental Geology – R. Torres, expected Spring 2007, McMillan Publishers

## **PROPOSALS**

### **Funded**

NSF-NCED, Support to host an international AGU Chapman Conference on Salt Marsh Geomorphology, 2004.

NSF Hydrology, Intertidal hydrology and geomorphology, 2003-2005.

EPA STAR, Estuarine indicators, 2001-2006,.

NSF **CAREER Award**, A mechanism for rapid soil-water transport, 2001-2006.

NOAA, Tidal creek network analysis, 2002-2004.

USDA Forest Service, Water quality and runoff generation in tidal rivers, South Carolina, 2002-2003.

ORAU, New Faculty Award, 2002.

### **PROPOSALS - Pending**

NSF-OCE-Coastal Studies, Rainfall effects on intertidal zone carbon cycling, 2007-2010.

NSF-EAR-Hydrology, Dynamics of lateral unsaturated flow and flux estimates, 2007-2009.

NSF-EAR-Geomorphology, Intertidal zone hydrology and geomorphology, continuation, 2006-2008.

ONR-Coastal Geosciences, Geomorphic indicators of intertidal zone material strength, 2006-2008.

ONR-Coastal Geosciences, Effects of low tide rainfall on turbidity in denied areas, 2006-2008

## **SERVICE**

**Associate Editor**, *Water Resources Research*, 2003-2006

**Guest Editor**, *Estuarine, Coastal and Shelf Science*, 2004-2006.

**Panelist**, NOAA-NOS, EPA-ORD, NCER, 2005-2006

**Convener**, Chapman Conference, Saltmarsh Geomorphology: Physical and ecological effects on landform, Halifax, Nova Scotia, October 13-19, 2004, <http://www.geol.sc.edu/chapman>.

**Session Chair**, Geol. Soc. Am., Linking Sediment Dynamics and Geomorphology in Tidal Marshes and Estuaries, Philadelphia, PA, October 22-26, 2006.

SACNAS (Society for the Advancement of Chicano and Native American Scientists), Annual Meeting, Tampa FL, October 26-29, 2006.

Am. Geophys. Union, Fall Meeting, Coastal Zone Morphodynamics, San Francisco, CA, December 12-17, 2004.

### **Reviewer**

Journals:

*Water Resources Research, Journal of Geophysical Research, Journal of Hydrology, Estuarine Coastal and Shelf Science, Earth Surface Processes and Landforms, Hydrological Processes, Geophysical Research Letters, Marine Geology, International Association of Hydrologic Science, Japan Journal of Hydrology, Kuwaiti Journal of Earth Sciences, India Journal of Geology.*

Funding Agencies:

National Science Foundation, Environmental Protection Agency, NASA, NOAA, ONR (Office of Naval Research).



<b>CALFED 2006</b>	2007-8	2008-9	2009-10	<b>TOTAL</b>
start date July 1, 2007	YEAR 1	YEAR2	YEAR 3	
<b>A. SENIOR PERSONNEL</b>				
R. Torres	9720	15163	15770	40653
<b>B. OTHER PERSONNEL</b>				
Technician/Clerical Support	5000	5200	8112	18312
Graduate Students	22000	22880	23795	68675
<b>TOTAL SALARIES</b>	<b>36720</b>	<b>43243</b>	<b>47677</b>	<b>127640</b>
<b>C. FRINGE BENEFITS (fac, p doc:20%, stud: ac yr 0.06%, sum 8.45%)</b>	<b>3498</b>	<b>4632</b>	<b>5198</b>	<b>13328</b>
<b>TOTAL SALARIES AND FRINGE BENEFITS</b>	<b>40218</b>	<b>47875</b>	<b>52875</b>	<b>140968</b>
<b>D. PERMANENT EQUIPMENT</b>				
	0	0	0	
<b>TOTAL PERMANENT EQUIPMENT</b>	<b>0</b>	<b>0</b>	<b>0</b>	
<b>E. TRAVEL</b>				
<b>1. DOMESTIC TRAVEL</b>				
a. Travel to field sites (2 trips/yr)	3590	3590	1535	8715
b. National meeting	0	0	2718	2718
<b>TOTAL DOMESTIC TRAVEL</b>	<b>3590</b>	<b>3590</b>	<b>4253</b>	<b>11433</b>
<b>2. FOREIGN TRAVEL</b>				
none	0	0	0	
<b>TOTAL FOREIGN TRAVEL</b>	<b>0</b>	<b>0</b>	<b>0</b>	
<b>TOTAL TRAVEL</b>	<b>3590</b>	<b>3590</b>	<b>4253</b>	<b>11433</b>
<b>F. PARTICIPANT SUPPORT COSTS</b>				
none	0	0	0	
<b>TOTAL PARTICIPANT SUPPORT COST</b>	<b>0</b>	<b>0</b>	<b>0</b>	
<b>G. OTHER DIRECT COSTS</b>				
<b>1. MATERIALS AND SUPPLIES (items &lt; \$5000)</b>				
raingauge (x2)	560			560
OBS (x2)	7400			7400
data logger	2400			2400
field tools/sprinkler	1300			1300
disdrometer	4900			4900
batteries	300	300	300	900
<b>TOTAL MATERIALS AND SUPPLIES</b>	<b>16860</b>	<b>300</b>	<b>300</b>	<b>17460</b>
<b>2. TUITION</b>				
Tuition (2007- semester \$3869, summer \$364, increased by 5% each year)	8466	8889	9334	26689
<b>TOTAL TUITION</b>	<b>8466</b>	<b>8889</b>	<b>9334</b>	<b>26689</b>
<b>3. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION</b>				
figure production, pub page charges and meeting production	0	2000	2000	4000
<b>TOTAL PUB CHARGES</b>	<b>0</b>	<b>2000</b>	<b>2000</b>	<b>4000</b>
<b>4. CONTRACTUAL SERVICES</b>				
"Frontier Geosciences Inc" Metals Analyses of Sediment	30120	30120	0	60240
<b>TOTAL CONTRACTUAL SERVICES</b>	<b>30120</b>	<b>30120</b>	<b>0</b>	<b>60240</b>
<b>TOTAL OTHER DIRECT COSTS</b>	<b>55446</b>	<b>41309</b>	<b>11634</b>	<b>108389</b>
<b>H. TOTAL DIRECT COSTS</b>	<b>99254</b>	<b>92774</b>	<b>68762</b>	<b>304940</b>
<b>MODIFIED TOTAL DIRECT COSTS (MTDC)</b>	<b>90788</b>	<b>83885</b>	<b>59428</b>	<b>278250</b>
<b>I. INDIRECT COSTS @ 44% MTDC</b>	<b>39947</b>	<b>36909</b>	<b>26148</b>	<b>103005</b>
<b>0.440</b>				
<b>J. TOTAL REQUESTED-USC TORRES</b>	<b>139201</b>	<b>129684</b>	<b>94910</b>	<b>363795</b>
<b>5. SUBCONTRACTS</b>				
University of Oregon	164188	0	0	164188
USGS	349999	0	0	349999
	0	0	0	0
<b>TOTAL SUBCONTRACTS</b>	<b>514187</b>	<b>0</b>	<b>0</b>	<b>514187</b>
<b>IDC on subcontract at 44% of the first \$25000</b>	<b>22000</b>	<b>0</b>	<b>0</b>	
<b>TOTAL AMOUNT REQUESTED FROM CALFED</b>	<b>675388</b>	<b>129684</b>	<b>94910</b>	<b>899982</b>

<b>CALFED 2006</b>	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6	Task 7	<b>TOTAL</b>
start date July 1, 2007								
<b>A. SENIOR PERSONNEL</b>								
R. Torres	4065	12196	8131	8131	4065	2033	2033	<b>40653</b>
<b>B. OTHER PERSONNEL</b>								
Technician/Clerical Support	3662	3662	4578	3662	916	916	916	<b>18312</b>
Graduate Students	0	13735	24036	20603	3434	3434	3434	<b>68675</b>
<b>TOTAL SALARIES</b>	<b>7728</b>	<b>29593</b>	<b>36745</b>	<b>32396</b>	<b>8415</b>	<b>6382</b>	<b>6382</b>	<b>127640</b>
<b>C. FRINGE BENEFITS (fac, p doc:20%, stud: ac yr 0.06%, sum 8.45%)</b>	<b>807</b>	<b>3090</b>	<b>3837</b>	<b>3383</b>	<b>879</b>	<b>666</b>	<b>666</b>	<b>13328</b>
<b>TOTAL SALARIES AND FRINGE BENEFITS</b>	<b>8535</b>	<b>32683</b>	<b>40582</b>	<b>35778</b>	<b>9293</b>	<b>7048</b>	<b>7048</b>	<b>140968</b>
<b>D. PERMANENT EQUIPMENT</b>								
<b>TOTAL PERMANENT EQUIPMENT</b>								
<b>E. TRAVEL</b>								
<b>1. DOMESTIC TRAVEL</b>								
a. Travel to field sites (2 trips/yr)	0	2615	3486	2615	0	0	0	<b>8715</b>
b. National meeting	0	815	1087	815	0	0	0	<b>2718</b>
<b>TOTAL DOMESTIC TRAVEL</b>	<b>0</b>	<b>3430</b>	<b>4573</b>	<b>3430</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>11433</b>
<b>2. FOREIGN TRAVEL</b>								
none								
<b>TOTAL FOREIGN TRAVEL</b>								
<b>TOTAL TRAVEL</b>	<b>0</b>	<b>3430</b>	<b>4573</b>	<b>3430</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>11433</b>
<b>F. PARTICIPANT SUPPORT COSTS</b>								
none								
<b>TOTAL PARTICIPANT SUPPORT COST</b>								
<b>G. OTHER DIRECT COSTS</b>								
<b>1. MATERIALS AND SUPPLIES (items &lt; \$5000)</b>								
raingauge (x2)	0	560	0	0	0	0	0	<b>560</b>
OBS (x2)	0	7400	0	0	0	0	0	<b>7400</b>
data logger	0	2400	0	0	0	0	0	<b>2400</b>
field tools/sprinkler	0	1300	0	0	0	0	0	<b>1300</b>
disdrometer	0	4900	0	0	0	0	0	<b>4900</b>
batteries	0	900	0	0	0	0	0	<b>900</b>
<b>TOTAL MATERIALS AND SUPPLIES</b>	<b>0</b>	<b>17460</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>17460</b>
<b>2. TUITION</b>								
Tuition (2007- semester \$3869, summer \$364, increased by 5% each year)		8007	10676	8007				<b>26689</b>
<b>TOTAL TUITION</b>		<b>8007</b>	<b>10676</b>	<b>8007</b>				<b>26689</b>
<b>3. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION</b>								
figure production, pub page charges and meeting production	0	1200	1600	1200	0	0	0	<b>4000</b>
<b>TOTAL PUB CHARGES</b>	<b>0</b>	<b>1200</b>	<b>1600</b>	<b>1200</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>4000</b>
<b>4. CONTRACTUAL SERVICES</b>								
"Frontier Geosciences Inc" Metals Analyses of Sediment	0	0	30120	30120	0	0	0	<b>60240</b>
<b>TOTAL CONTRACTUAL SERVICES</b>	<b>0</b>	<b>0</b>	<b>30120</b>	<b>30120</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>60240</b>
<b>TOTAL OTHER DIRECT COSTS</b>	<b>0</b>	<b>26667</b>	<b>42396</b>	<b>39327</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>108389</b>
<b>H. TOTAL DIRECT COSTS</b>	<b>8535</b>	<b>62780</b>	<b>87551</b>	<b>78535</b>	<b>9293</b>	<b>7048</b>	<b>7048</b>	<b>304940</b>
<b>MODIFIED TOTAL DIRECT COSTS (MTDC)</b>	<b>8535</b>	<b>54773</b>	<b>76875</b>	<b>70528</b>	<b>9293</b>	<b>7048</b>	<b>7048</b>	<b>278250</b>
<b>I. INDIRECT COSTS @ 44% MTDC</b>	<b>3755</b>	<b>24100</b>	<b>33825</b>	<b>31032</b>	<b>4089</b>	<b>3101</b>	<b>3101</b>	<b>103005</b>
0.440								
<b>J. TOTAL REQUESTED-USC TORRES</b>	<b>12290</b>	<b>86880</b>	<b>121376</b>	<b>109567</b>	<b>13382</b>	<b>10150</b>	<b>10150</b>	<b>363795</b>
<b>5. SUBCONTRACTS</b>								
University of Oregon			82094	82094				<b>164188</b>
USGS		175000			70000	70000	34999	<b>349998</b>
<b>TOTAL SUBCONTRACTS</b>	<b>0</b>	<b>175000</b>	<b>82094</b>	<b>82094</b>	<b>70000</b>	<b>70000</b>	<b>34999</b>	<b>514186</b>
IDC on subcontract at 44% of the first \$25000								
<b>TOTAL AMOUNT REQUESTED FROM CALFED</b>	<b>12290</b>	<b>261880</b>	<b>203470</b>	<b>191661</b>	<b>83382</b>	<b>80150</b>	<b>45149</b>	<b>752683</b>

## Torres Budget Justification

### **A. Senior Personnel**

Funds are requested for one month of summer salary for the PI for year 1 and 1.5 months of salary for year 2 and 3. The added half month is commensurate with the large amount of field work. The initial month salary is \$9720. The PI will be responsible for coordinating the installation of equipment, data QA&QC, data management and data analyses, and he will make periodic site visits to monitor the graduate student and collaborator protocol and progress. The PI will direct graduate student led manuscript preparations, and will oversee and manage collaborators and scholarly productions from the team of scientists..

### **B. Other Personnel**

Funds are requested to support one graduate student assistant at \$22,000 per year, with a 4% cola on year 2. The student will conduct the installation and maintenance of equipment and data acquisition for the life of the experiment. The graduate student but will be directed by the PI.

### **C. Fringe Benefits**

Fringe benefits for the PI are calculated at 20% of salary. Student rate is 0.06% when enrolled for courses. The graduate and undergraduate students will be enrolled for one credit hour during each of two summer sessions per year.

### **D. Equipment**

None

### **E. Travel**

Funds are requested to support PI and graduate student travel to the study sites. Initially the PI will accompany the graduate and undergraduate students in field work. Later just the grad student and/or the undergrad will perform maintenance. There will be a total of two 14-day trips per year. Lodging is estimated at 110/night, car rental at \$200, gas \$150, incidentals \$100 and per diem for the PI and field assistant is \$32 per day.

I also request \$2718 for the PI and graduate student to present research results at a professional meeting, most likely the Fall AGU meeting. To keep costs down we will share a hotel room. The total includes hotel, airfare, per diem, registration, airport transportation, and incidentals.

### **F. Participant Support Costs**

None

### **G. Other Direct Costs**

#### **1. Materials and Supplies**

Funds are requested to support the cost of consumable supplies. TI350 raingauges are \$280 each. Two D-A OBS turbidity meters at and a Campbell CR10X data logger at \$2700 and \$3400 respectively. Field tools and sprinkler apparatus are requested at \$1300. A disdrometer will be used to estimate rainfall size and velocity for KE analyses and \$300 per year are requested for batteries.

#### **2. Publication/Documentation/Dissemination Costs**

PI requests a total of \$2000 for years 2 and 3 to support page charges and production costs, and meeting presentation production.

#### **3. Contractual Services**

Frontier Geosciences will analyze our sediment sample for total mercury and methyl mercury, and for a suit of 6 toxic metals. Quotes from the company are attached.

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## Torres Budget Justification

### 6. Tuition Cost

Tuition is \$3869 per semester, plus \$364 per summer for a single credit hour during summer session one. Total for year one is \$8466. These values are increased by 5% for year two. Tuition is requested for one student for 2 years.

### 7. Subcontract

Details on subcontract to the University of Oregon and the USGS are attached.

### **I. Indirect Costs**

Indirect costs are calculated on all budget items with the exception of equipment and tuition. The indirect cost rate is 44% of the MTDC (modified total direct cost. IDC is also taken for subcontracts to UO and the USGS. IDC is 44% of the first \$25000 of each subcontract.

## **Budget Justification**

### **Salaries**

#### **Senior Personnel**

Funds are requested for 1 month of salary per year for year 1, and 1.5 months of salary per year in year 2 for Miguel Goni. Goni will participate in all aspects of the work, sampling, including bulk and molecular-level analyses of suspended OM samples. He will oversee one faculty research assistant (FRA) and one undergraduate student throughout the duration of the project. He will be in charge of writing and interpreting the results. As an associate professor at COAS, M. Goni is expected to raise 65% of his annual salary through externally funded grants. The salary request is concordant with his involvement in this project.

#### **Students**

Funds are requested to cover 3.5 months of salary per year in years 1 and 2 of the project for one faculty research assistant (FRA). The FRA will work on the organic compositions of POM samples, including isotopic (d13C, d15N) and PAH compositions of POM samples. Funds are also requested to cover the salary of one undergraduate student per year for years 1 and 2 of the project. Individual undergraduate students will be recruited through the Native Americans in Marine and Space Science Program (NAMSS) at Oregon State University ([www.coas.oregonstate.edu/index.cmf](http://www.coas.oregonstate.edu/index.cmf)) and through REU internships within the Environmental Sciences Program (Oceanography Minor). The responsibilities of the undergraduate students will be to help carry out bulk elemental measurements of POM samples.

Fringe benefits are apportioned according to Oregon State University regulations.

### **Travel**

Funds are requested for a planning trip for 1 person (1 week) in year 1 and two 2-week sampling trips for 2 people to the study site in California (one in year 1, one in year 2). In year 2, funds for a trip to a national meeting are also requested.

### **Other Direct Costs**

#### **Materials and Supplies**

Funds are requested for materials and supplies associated with analyses of elemental and PAH analyses. They include analytical supplies for elemental and isotopic analyses (chemicals, gases), as well as supplies for PAH analyses by solvent extraction and GC-MS analyses (solvents, standards, high purity gases, vials, capillary columns, septa, syringes). The distribution of the requested funds reflects estimates based on 100 samples we expect to analyze.

#### **Publication Costs**

Funds are requested for costs associated with publication and dissemination

#### **Computer Services**

Funds are requested to cover the costs and fees associated with Research Computing Services (RCS) at COAS, which includes access to hardware and software, technical support, internet and web services.

#### **Other**

Funds are requested to cover the shipping of samples, long distance telephone, and mailing costs. Funds are also requested to cover the use of the stable isotope mass spectrometry instrumentation in the Stable Isotope Mass Spectrometer Facility. The use of the facility will cover d13C analyses of 100 samples per year.

### **Other Indirect Costs**

The negotiated F&A rate is 41.5% for modified direct costs, which include all direct costs except equipment and graduate student tuition.

## USGS Budget Justification

The USGS uses full cost accounting to determine budgetary charges. This budget summarizes full costs incurred by the USGS to perform the proposed work.

### Senior Personnel

The requested funds will be used to cover salaries for Jacob Fleck (GS-11) at 1/3 full time (700 hrs/yr) for project chief duties, Bryan Downing (GS-11) at 1/3 full time (700 hrs/yr) for field and technical expertise, and Brian Bergamaschi (GS-14) at 10% full time (200 hrs/yr) for project supervision and scientific review.

### Other Personnel

Additional salary and benefit costs will cover lab and field technicians (GS-7, GS-8) and modeling help (GS-11). They will be called on as needed within the budgeting limitations.

### Fringe Benefits

Fringe benefits are calculated at 28% of base salary.

### Travel

Travel to the field sites and side trips is estimated at 90 miles away. At 0.485/mile each trips costs \$88. We anticipate 16 trips plus incidentals such as bridge tolls, entrance fees, toll roads.

### Materials and Supplies

The costs for supplies will be used to cover expendable necessities required to complete the field and laboratory tasks. These items include glassware and disposable wares for clean sampling.

### Contractual Services

Funds are requested for assistance to measure and model hydrodynamic and partitioning processes. We will work with George Aiken and David Schoelhammer on these efforts.

## Explanation of cost-share and matching funds

The USGS will provide cost-share match for the proposed work through the no-cost use of equipment required for the successful completion of the project. The fair market value of equipment rental that would be charged the project is used to determine the match. This results in a match of \$150,000. Additional cost-share will be provided through a salary match from federal salaries, this match amounts to \$50,000. Competitive matching funds will be provided through the use of the California Water Science Center's Federal Matching Funds process. This process awards extra funds to projects that compete for additional appropriated dollars. The requested funds for this project amount to \$100,000, over the three fiscal years. In total, the cost-share and additional matching funds contributed by the USGS for completion of this work add up to \$300,000.

Signature

[California Home](#)

## Signature

The applicant for this proposal must submit this form by printing it, signing below, and faxing it to +1 877-408-9310. Send exactly one form per transmission.

*Failure to sign and submit this form will result in the application not being considered for funding.* The individual submitting this proposal will receive e-mail confirmation as soon as this signature page has been processed.

The individual signing below declares that:

- all representations in this proposal are truthful;
- the individual signing the form is authorized to submit the application on behalf of the applicant (if applicant is an entity or organization);
- the applicant has read and understood the conflict of interest and confidentiality discussion under the Confidentiality and Conflict of Interest Section in the main body of the PSP and waives any and all rights to privacy and confidentiality of the proposal on behalf of the applicant, to the extent provided in this PSP; and
- the applicant has read and understood all attachments of this PSP.

**Proposal Title:** A Non-Point Source of Contaminants to the Estuarine Food Web: Mobile Particles to the Intertidal Zone

**Proposal Number:** 2006.01-00 ~~70~~ 70

**Applicant Organization:** University of South Carolina Research Foundation

**Applicant Contact:** Mr. Steven Etheredge

8/31/06

**Applicant Signature**

**Date**

R. Steven Etheredge, Director, Pre-Award Services  
Sponsored Awards Management



# Quality Assurance Plan

**Frontier GeoSciences, Inc.**

414 Pontius Avenue N.  
Seattle, WA 98109  
206-622-6960

**Effective January 17, 2005**

Amendment 2.1 August 1, 2006

**Prepared by:**

Will, Hagan, Quality Assurance Officer  
Shelly Fank, Quality Assurance Coordinator  
Amber Steward, Laboratory Manager  
Carl Hensman, Ph.D. Technical Director

**With concurrence of:**

Shelly Fank, Quality Assurance Officer



Patrick Garcia-Strickland, Laboratory Manager  
Carl Hensman, Ph.D., Lead Technical Director  
Curtis D. Pollman, Ph.D., Technical Director, Chief Scientist, & CEO



# 1.0 Quality Assurance Policies

## 1.1 Quality Assurance Policy Statement

**F**rontier Geosciences has a strong and vital commitment to quality assurance (QA), viewing it as both a program and a philosophy. We begin quality control at the bench level, and continuously work to improve our processes at the management level. Our focus is on the prevention of analytical problems. With our rigorous training program, Frontier's laboratory staff learns how to troubleshoot and initiate corrective actions. Our management style is to solicit process improvements and problem solving from our technicians and analysts, then use management for implementation. This helps keep management informed and up to date while at the same time promoting the professional growth of our employees and keeping our lab on the cutting edge of analytical technology.

Frontier is dedicated to providing uncompromisingly high-quality data that meets the needs of the environmental, geochemical, human health, and industrial communities. Frontier recognizes that accurate and precise data depends on these basic principles:

- Sample integrity must be preserved.  
All documented sample handling procedures for preservation, custody, storage, labeling and record keeping are rigorously followed.
- Trace metal-free ("ultra-clean") sample handling must be employed.  
All samples to be analyzed for low-level or ambient metals concentrations are handled according to established protocols. This includes the use of class-100 clean areas, clean room gloves, and pre-tested and approved reagents, water, and equipment. High-level samples are kept segregated from ultra-clean samples during storage and sample preparation.
- Approved analytical methods must be followed.  
The Analyst's fundamental understanding of analytical methods is paramount for effective quality control. Emphasis on scientific understanding and adherence to procedure is part of every Analyst's training. Quality control results from each method are evaluated to identify and correct any method weakness, and to detect any need for further training.

- Analytical instrumentation must be in proper working order.  
Optimum instrument performance is ensured by analyzing daily calibration and verification samples. Preventative maintenance is performed on a regular basis and is well documented.
- Raw data must be properly reduced and accurately transcribed into the correct reporting format.
- Various levels of data review, from acquisition to the final report, are performed to minimize error.

## 1.2 Project Acceptance Policy

**P**roject Managers are responsible for deciding whether to accept new work. When in doubt, prospective projects must be reviewed by the Management Committee or a committee member before they are accepted. This generally pertains to large-scale or non-routine projects. Regarding all other new work, it is the sole responsibility of the Project Manager to evaluate whether it can be completed to meet the client's project goals, data quality objectives, and deadlines.

Please see amendment 3.0, page 48

## 1.3 Ethics Policy

**I**t is of paramount importance that all reported results and interpretations are objective and honest. Although individuals within the company may differ on the political implications of various results, Frontier must remain above this in its research and data reporting. All obtained results must be reported with complete honesty, with no regard for an expected, or preferred (by client or analyst) outcome.

In cases where the “best” or “most accurate” data have to be selected from an analytical set (or if data must be rejected), all criteria used in the evaluation must be clear and well document-

ed. That documentation must be readily available for outside review. There may be times when the decision to reject data is not absolutely clear. Any time the decision is ambiguous, it must be made with management consent. Unambiguous decisions need not be overseen, or explained, but all data must be presented and noted on the original data set. Falsification of data or its deliberate suppression are considered grounds for immediate employment termination.

All personnel are required to adhere to Frontier's ethics policy. Any staff member witnessing an act that may violate the ethics policy is required to report the incident to management. The reporting staff member may maintain anonymity. Several avenues are available for staff to report suspect behavior: they may directly confront the offending staff member; they may report the instance to the staff member's direct supervisor, the Laboratory Manager, or any member of the Management Committee. The important factors are for management to be aware of the situation, and for all personnel to feel comfortable reporting suspect behavior.

Violations of Frontier's ethics policy can negatively affect those involved as well as the company as a whole. Individuals may face reputation damage, disciplinary action, job dismissal, legal action, or fines. Furthermore, the entire company may face a loss of business, legal action, fines, or even mandatory shutdown.

Ethics training is a requirement for each technical staff member. Our Ethics Training Program is administered by the QA Office and emphasizes the prevention of unacceptable activities. Training is provided for all new staff members and is documented and kept on file in the QA Office.

## **1.4 Financial Pressure Policy**

**F**rontier's primary purpose is to produce high quality, scientifically coherent data. In order to achieve this, the laboratory staff requires certain resources. One principal resource, commonly overlooked in routine laboratories, is time. Laboratory quotas (quantity vs. quality) have no part in Frontier's operating philosophy. To constantly improve the quality of their data, analysts at Frontier are encouraged to use their initiative and scientific intuition. Frontier's analysts can count on support for trouble-shooting and analyst-initiated repeat analyses because the production of sound scientific data is more important than the volume of samples analyzed. Therefore, analysts and technicians should distance themselves from any commercial, financial, or other undue pressures that may adversely affect the quality of their work. If staff members feel pressure in any of these areas, such that it is counter-productive

to Frontier's analytical goals, they should bring it up with the Laboratory Manager or any member of the Management Committee.

## 1.5 Confidentiality Policy

All of Frontier's controlled documents, inventions, ideas, processes, formulas, know-how, improvements, methods, designs, and techniques shall be treated as proprietary information and shall be protected by the Washington State Trade Secret Act, RCW 19.108 et seq., and other laws. Proprietary information shall be kept in the strictest confidence and shall not be used or appropriated for the benefit of any party without the prior written consent of Frontier.

Proprietary information shall not be summarized, copied, reproduced electronically or by any other method, and shall not be disclosed, distributed, disseminated, or transmitted in any manner or to any party without the prior written consent of Frontier. All proprietary information (including any originals, copies, summaries, or other reproductions thereof) shall be and at all times remain the property of Frontier and shall be returned to Frontier upon demand.

It is also Frontier policy to ensure the confidentiality of proprietary client information. Such information shall be released to a third party only with the express verbal or written permission of the client, except as required by law.

## 1.6 Subcontracting Policy

Project Managers will choose subcontracting laboratories based on reputability, client/project goals, and/or subcontracting agreements. If subcontracting agreements are warranted, they will be developed specifically for the project in question, and subcontracting laboratories will be held responsible for guidelines/goals outlined in the agreement. The QA Office keeps all subcontracting laboratory certifications and company profiles in a file provided by the Project Manager. This file is available to all clients for review, except in cases where client confidentiality might be compromised.

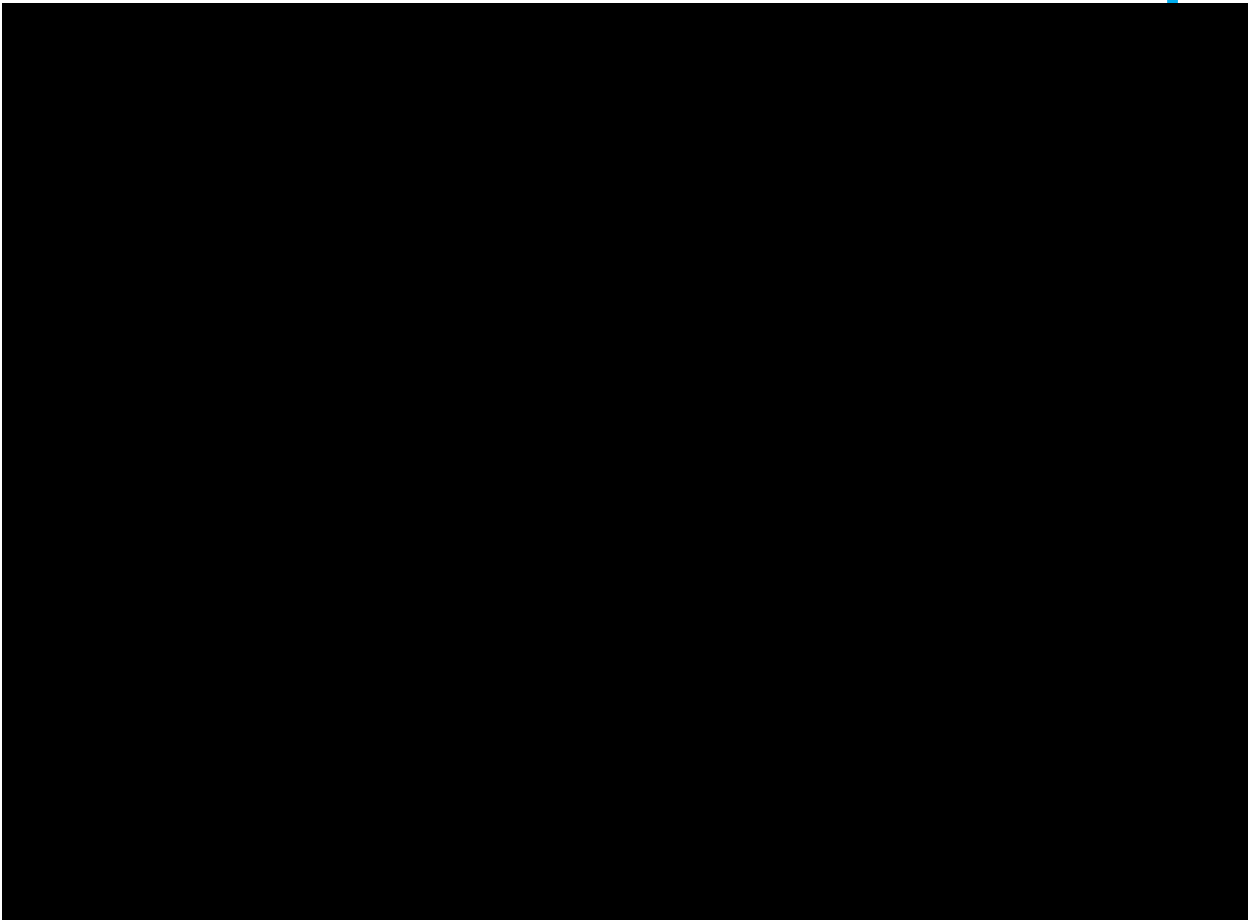
At the Project Manager's discretion, laboratory services will be subcontracted for specialties such as analyses outside our scope or sample preparation requiring specialty instrumentation. Additionally, subcontracting services may be used on large-scale projects where instrumentation and/or staff size limitations require them.

## 2.0 Organization and Responsibilities

### 2.1 Organization Chart

(for the most current version of this chart, please contact Frontier's Human Resources office)

Please see Amendment 1.2.



### 2.2 Laboratory Manager and Technical Director

**T**he Laboratory Manager reports directly to the President and is a member of the Management Committee. The Laboratory Manager's goal is to consistently produce high-quality data while maintaining superior turn-around-time, cost effectiveness, sustainable lab practices, employee job satisfaction, and exceptional customer relations.

The Laboratory Manager has ultimate responsibility for the quality of all analytical laboratory data, reports, practices, and safety. The Laboratory Manager ensures that data meets all quality control requirements, or takes appropriate and documented corrective action if it does not.

Finally, it is the Laboratory Manager's responsibility to ensure that all staff members understand and adhere to the QAP and relevant SOPs.

For the purposes of NELAP compliance, a Technical Director must be named. Currently one of Frontier's Principal Investigators fills the role of Technical Director. There are various deputies who are responsible for individual groups within the company. In the absence of the Technical Director, the deputies carry out the responsibilities of these positions.

- Deputy Technical Director, Analyst Group—Analyst Group Leader
- Deputy Technical Director, Lab Assistant Group—Lab Assistant Group Leader
- Deputy Technical Director, Project Management Group—Project Management Group Leader

### 2.3 Quality Assurance Officer

The QA Officer's goal is to continuously improve the laboratory's quality assurance/quality control processes in a manner consistent with the company mission statement. This goal requires support from the Management Committee and laboratory staff. The QA Officer ensures that all laboratory decisions are considered from a QA standpoint.

Specifically, the QA Officer has the following responsibilities relating to laboratory QA systems:

- coordinates training procedures for laboratory staff, including QA orientations and ethics training
- oversees facilities testing programs (for reagent water, vats, bottles, equipment, and air)
- performs review of client reports and high-QA raw data
- functions as QA Group Leader, scheduling the workload of the QA group
- investigates rejected datasets, customer complaints, and corrective actions
- administers state certifications
- manages proficiency tests and laboratory intercomparison studies
- maintains controlled documents, including the laboratory QAP and SOPs
- provides staff members with QA information as needed
- follows procedures described in the QAP and all applicable SOPs
- may deviate from written procedures per FGS-087, Deviation from Policy
- performs other relevant tasks associated with Frontier's QA requirements

The QA Officer is responsible for reporting the progress and overall performance of quality assurance/quality control measures to the Management Committee. This is communicated by Internal Audit Reports, memorandums, and QA Program Quarterly Reports. The QA Officer works closely with the Laboratory Manager and Group Leaders to ensure that all staff members adhere to the QAP and relevant SOPs, and that scientific excellence remains Frontier's top priority.

In the absence of the QA Officer, the Deputy QA Officer carries out the responsibilities of the position.

## 2.4 Technical Staff

### Analyst Group Leader:

- schedules all analytical work
- oversees employee training, including sample preparation techniques and analyses, and reviewing the work of analytical laboratory staff members during training periods
- ensures that training protocols are up-to-date and properly documented
- acts as a lead, answering procedural or analytical questions, and providing corrective action recommendations
- ensures that instrument maintenance is being performed, and coordinates troubleshooting
- participates in the development and improvement of methods
- provides scientific insight regarding analytical issues
- provides input regarding employee performance
- ensures that an adequate supply of laboratory materials is always on hand
- maintains and promotes safety and cleanliness in the laboratories, in cooperation with the Health & Safety Officer
- reports health and safety issues/problems to the Health & Safety Officer
- performs all Analyst duties
- follows procedures described in the QAP and all applicable SOPs and ensures that these protocols are being followed and updated to reflect current methodologies
- may deviate from written procedures per FGS-087, Deviation from Policy
- performs any other tasks assigned by the Laboratory Manager



#### **Analyst:**

- has completed a number of skill sets successfully, and has demonstrated competency at applicable duties (sample preparations and/or analyses)
- prepares and analyzes samples, calculates and evaluates all data, and submits raw data (fully calculated) to Technical Data Services Group
- performs any necessary corrections to datasets in a timely manner
- is responsible for reviewing all COC forms and project sheets to be sure the samples are being analyzed correctly and the proper QC is being performed
- works to ensure the generation of high quality data
- performs instrument maintenance
- keeps lab very clean, always cleaning an area of the lab after using it
- follows procedures described in the QAP and all applicable SOPs
- may deviate from written procedures per FGS-087, Deviation from Policy
- performs any other tasks assigned by a Group Leader or the Laboratory Manager

#### **Laboratory Assistant Group Leader:**

- directly supervises the decontamination of sampling equipment
- assigns work on a daily basis to Sample Custodians and Laboratory Assistants in the Shipping & Receiving/Bottle Washing (S&R/BW) Group
- oversees employee training for decontamination processes, ensures that protocols are up-to-date and are being followed, and reviews the work of all staff members during their training period
- ensures and documents initial and on-going Laboratory Assistant proficiency
- acts as a lead, answering protocol questions and providing corrective action recommendations.
- responsible for ensuring that SOPs are being followed, or updating SOPs to reflect the current methodologies
- ensures that instrument maintenance is being performed, and coordinates troubleshooting
- participates in the development and improvement of methods
- conducts employee performance reviews
- ensures that an adequate supply of all laboratory materials is on hand
- maintains and promotes safety and cleanliness in the laboratory, in cooperation with the Health & Safety Officer

- performs all relevant S&R/BW Group Laboratory Assistant duties
- follows procedures described in the QAP, and all applicable SOPs
- may deviate from written procedures per FGS-087, Deviation from Policy
- performs any other tasks assigned by the Laboratory Manager

#### Laboratory Assistant:

- takes directions from the Laboratory Manager, a Project Manager, and/or a Group Leader regarding the immediate processing of samples as they enter the laboratory
- filters, preserves/oxidizes, homogenizes, and/or checks the pH of samples
- calibrates pipettes
- prepares ICP-MS tubes for use
- cleans the laboratory daily (takes out garbage, wipes down counters, changes sticky mats, etc.)
- takes samples to the storage container
- performs sample preparations
- may perform simple analyses (such as TSS, total solids, or colorimetric determinations for iron or hexavalent chromium) under the direction of a Group Leader
- follows procedures described in the QAP and all applicable SOPs
- may deviate from written procedures per FGS-087, Deviation from Policy
- performs any other tasks assigned by a Group Leader, the Laboratory Manager, or requested by an Analyst
- track sample storage
- responsible for receiving all items (documents, supplies, and sample shipments) delivered by courier services
- ships sample containers/equipment to clients for sample collection, as well as, if requested, returning samples to clients after analysis
- provides information to clients about ordering sample containers, sample collection, sampling equipment, and sample receipt
- performs daily calibration of the balances, recording balance data in a traceable log-book
- monitors the temperatures of the freezer and refrigerators, recording temperature data in a traceable log-book
- maintains and monitors the sample storage logbook, and oversees on-site sample disposal
- responsible for the decontamination of laboratory equipment and of sample equip-

ment prior to sample collection

- organizes and maintains the sampling equipment library
- monitors and maintains the ultra-pure water system used for equipment decontamination
- responsible for maintaining the ovens used for equipment decontamination
- cleans the shipping and receiving area, the bottle washing room, and the bottle storage room daily (takes out garbage, cleans and stores coolers, breaks down boxes, tidies supplies, wipes down fume hood, replaces blotter paper, changes sticky mats, etc.)
- deep cleans the bottle washing room, the bottle storage room, and the shipping and receiving area weekly
- neutralizes and disposes of chemical waste
- follows procedures described in the QAP and all applicable SOPs
- may deviate from written procedures per FGS- 087, Deviation from Policy
- performs any other tasks assigned by the Group Leader, the Laboratory Manager, or requested by an Analyst

#### Technical Data Services Group Leader:

- acts as a lead, answering procedural or technical questions, and provides corrective action recommendations
- supervises and schedules TDS group duties
- ensures that training protocols are up-to-date
- reviews the work of all new staff members during their training period
- ensures and documents initial and on-going proficiency
- ensures that the SOPs and QAP are being followed
- updates SOPs to reflect current methodologies
- provides input for employee performance reviews
- works with the QA group, Lab Manager and Project Managers to maintain, promote and improve data quality and efficiency
- reports any analytical issues/problems to the QA Officer and Lab Manager or Project Manager
- may deviate from written procedures per FGS-087, Deviation from Policy
- performs any other tasks assigned by the Lab Manager

### Technical Data Specialist:

- works on projects assigned by the TDS Group Leader
- peer-reviews all data generated according to specifications detailed in the QAP and Frontier SOPs
- highlights or flags any obvious problems with the data or any QC results that are out of the control limits. The TDS specialist is responsible for following up on any outstanding issues
- maintains and archives all original (both electronic and hardcopy) datasets and reports in an organized and accessible manner
- maintains data archived lists, and helps locate archived datasets and reports for other staff members
- helps Project Manager review report tables for sample results and QC results, according to the project requirements
- generates electronic data deliverables (EDDs) to the specifications of the client and works with the Project Manager to ensure that EDDs are accurate and acceptable
- peer reviews EDDs before submittal to the client
- performs correction of EDDs when necessary
- enters method detection limit (MDL) spike data
- may deviate from written procedures per FGS-087, Deviation from Policy
- performs any other tasks as assigned by the TDS Group Leader or Laboratory Manager

### Project Management Group Leader:

- oversees and organizes the Project Management group
- reviews all major requests for proposals and assigns response to appropriate Project Manager
- reviews all quotes and proposals and assigns projects to appropriate Project Manager
- serves as a mentor regarding client issues, analytical review of data, and report development
- responsible for organizing and conducting new staff training for Project Management group
- conducts ongoing review of all reports and quotes developed by new Project Management staff and/or coordinates review by senior Project Management staff

- conducts marketing and sales efforts for Analytical Laboratory group
- responsible for communicating information to Project Management group and other Group Leaders through meetings
- conducts employee performance reviews
- performs any task assigned by Laboratory Manager
- performs all Project Manager tasks

#### **Project Manager:**

- works on projects assigned by the Laboratory Manager and Project Management Group Leader
- responds to all client issues (bottle orders, questions about reports, etc.)
- maintains responsibility for assigned projects from beginning to end (may include helping to log in and track samples and approve sample disposal)
- works with the Laboratory Manager and Group Leaders to ensure that all appropriate information is recorded on clear and accurate project sheets
- performs any secondary manipulation of data necessary, and evaluates data for scientific coherence
- contributes any “value added” items to reports (e.g., evaluation of results, what results “mean”)
- ensures that all QC requirements are met and/or provides appropriate and documented recommendations for corrective action
- finalizes analytical reports (including a narrative of any analytical issues) ensuring compliance with FGS-104, Generation of Hardcopy Sample Results Report
- generates EDDs for the client, or, with the approval of the Laboratory Manager, delegates the generation of EDDs to the Technical Data Services group
- sends reports to clients
- submits invoice requests to the accounting group
- gives copies of reports and invoice requests to the Laboratory Manager or Project Management Group Leader for review (new Project Managers only)
- provides backup for other Project Managers when they are out of the office
- assists in business development
- responds to new client phone calls and proposals
- prepares quotes and proposals
- provides background project information to analytical group
- performs any other tasks assigned by the Laboratory Manager, Project Management Group Leader

- follows procedures described in the QAP and all applicable Frontier SOPs
- may deviate from written procedures per Frontier FGS-087, Deviation from Policy

The Project Coordinator (PC) performs many of the same daily tasks as Project Managers identified above. Project Coordinators assist the Project Manager and share working knowledge of ongoing projects. They often develop reports and maintain client relations. However, Project Managers are solely responsible for overall project management and must remain available for oversight of the project.

## 2.5 Laboratory Capabilities

**F**rontier is accredited by the California Department of Health Services, Florida Department of Health, Louisiana Department of Environmental Quality, Minnesota Department of Health, New Jersey Department of Environmental Protection, New York Department of Health, Washington Department of Ecology, and Wisconsin Department of Natural Resources. We have experience performing analytical chemistry, field sampling, and bench-top research to the QA specifications of the US EPA Superfund and CLP programs.

Frontier worked with the EPA to develop and codify techniques for ultra-clean sampling (US EPA Method 1669) and ultra-low level mercury analysis (US EPA Method 1631). We also codified our technique for methyl mercury in water (EPA Draft Method 1630). In addition, Frontier helped develop EPA Draft Methods 1632 (As by HG-CT-GC-AAS), 1637 (trace elements by GF-AAS with preconcentration), 1638 (trace elements by ICP-MS), 1639 (trace elements by GF-AAS), and 1640 (trace elements by ICP-MS with preconcentration). Frontier was selected as the EPA referee laboratory for the validation studies for all of the above EPA 1600-series methods.

## 3.0 Quality Assurance Objectives

### 3.1 Data Quality Objectives

**F**rontier's data quality objectives (DQOs) ensure production of high quality, coherent data. Our DQOs consists of five elements: precision, accuracy (bias), representativeness, comparability, and completeness.

**Precision** is a measure of our ability to use our methods to analyze a sample repeatedly and get the same results each time. To demonstrate the precision of a method, sample replicates are analyzed and their results compared.

**Accuracy**, or bias, is a measure of how close the result is to the true or expected value of target analyte in the sample. Accuracy may be determined by the analysis of reference materials, blank spikes, and matrix spikes, where the result can be compared with a true or expected value. Accuracy and bias can also be evaluated holistically, as through system mass-balance, or by other appropriate measures of scientific coherence.

**Representativeness** describes how well a single sample can characterize the conditions of the entire sample population. Appropriate sampling techniques and artifact-free procedures, combined with sample homogenization, help to achieve representative data.

**Comparability** is a particularly important QA criterion for ongoing projects. Individual data sets are evaluated with respect to other data from that project to ensure validity and scientific coherence.

**Completeness** is a measure of how many data points collected are usable; Frontier considers 95% of usable data to be an acceptable value for completeness.

Frontier provides data packages in one of two Quality Assurance formats. "Standard-Level" and "High-Level". The two different levels do not represent differences in analytical quality. Rather, the differences are in the degree of documentation, and therefore the ability to defend the data in legal proceedings. The quality of data produced under the two QA reporting schemes, as measured by quantitative indicators such as precision, accuracy (bias), and detection limits, are equivalent.

In addition, Frontier will provide custom QA/QC packages to meet specific project needs.

## 4.0 Sample Handling

### 4.1 Sampling Procedures

All samples for trace metals analysis must be collected in a manner that neither contaminates, loses, nor changes the chemical form of the analytes of interest. The appropriate sampling technique may vary depending on the location, sample type, sampling objective or client sampling plan.

Frontier SOP FGS-008, “Ultra-Clean Aqueous Sample Collection” (Modified EPA Method 1669), should be referenced for sampling water matrices. Sediment, air, and tissue sampling protocols are project-dependent.

The use of appropriate sampling equipment and sample containers is an integral part of the sampling method. Frontier maintains a stock of sample bottles of the preferred types (Teflon, glass, HDPE, LDPE, polycarbonate) for ambient water sampling. Frontier cleans, tests, and bags these bottles according to procedures described in Frontier SOPs FGS-007 “Cleaning of Sampling Equipment and Bottles for Mercury Analysis” and FGS-065 “Cleaning of Sampling Equipment and Bottles for Analysis of Trace Metals.” Frontier routinely supplies these bottles to clients to facilitate sampling programs.

Frontier staff are experienced at selecting appropriate sampling techniques on the basis of data quality objectives and project requirements. The Frontier Project Manager should be contacted for direct consultation regarding sampling plans.

Sub-sampling in the laboratory must be done following protocols in Frontier SOP FGS-078, “Sample Preservation and Sub-Sampling.” This procedure aims to ensure thorough sample homogenization. Samples that are not properly homogenized may lead to irreproducible results.

### 4.2 Sample Acceptance

It is the client’s responsibility to provide a chain-of-custody (COC) form with samples. If no COC is provided, the Project Manager will be notified, and either the Sample Custodian or the Project Manager will attempt to contact the client (unless otherwise directed by the Project Manager). If the client is reached, but is unable to fax a copy of the COC, or if no COC has been generated, Frontier’s Sample Custodian will create one. If the Sample